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THE ORBIT OF ζ SAGITTARII.

R. G. AITKEN.

FOR POPULAR ASTRONOMY.

The bright star ζ Sagittarii, was found to be a close double star by Winlock at the Harvard College Observatory in July 1867. Measures were secured during the same year at Harvard and at Washington, but it was then neglected for eleven years, except for one night's uncertain observations at Harvard in 1869. In 1878 Burnham found the position angle of the pair to be in practical agreement with the discovery position, but reversed the quadrant. Still the two components were so nearly equal in brightness, and the zenith distance at which the star was necessarily measured at northern observatories, was so great, that it was doubtful whether there had been any motion in the interval. Burnham's subsequent measures, however, clearly prove that the pair was in orbital motion and that the period of revolution was short.

As early as 1886 Gore investigated the orbit of ζ Sagittarii and from the measures then available derived a period of 18.69 years. In 1893, Mr. J. W. Froley determined the period to be 17.715 years, and in 1895, See obtained a set of elements resembling Froley's in general, but with a period of 18.85 years.

The observations of the last few years, however, indicate that these periodic times are all too small and as the motion since 1895 has been rapid—through 120° of position angle—it seems probable that some improvement in the elements of the orbit may now be effected. I therefore recently collected all the published observations of this pair that I could find; and these with my own measures during the present year and a fine set which Mr. Innes kindly secured for me with the 18-inch MacClean refractor at the Cape of Good Hope, are given in the following table:

OBSERVATIONS OF ζ SAGITTARII.*

Date.	θ	ρ	Observer.	Nights.	Notes.
	°	″			
1867.60	258.8	0.68	Winlock	2	
67.62	274.7	——	Searle	2, 0	
67.80	260.8	0.48	Newcomb	2, 1	
69.74	352.7	——	C. S. Pierce	1, 0	
69.74	259.0	——	Winlock	1, 0	
78.70	84.2	0.42	Burnham	1	
79.71	54.8	0.3±	"	1	With 6-inch telescope.
80.62	62.1	0.55	"	2	
81.61	36.1	0.31	"	2	"Excessively difficult, meas. uncertain"
86.62	271.4	0.65	Hall	4	"Images always blurred."
86.74	271.1	——	Pollock	1, 0	
87.62	264.1	——	"	5, 0	
88.62	257.4	0.70	Burnham	6	
88.71	261.2	0.65	Leavenworth	1	Uncorrected measure.
89.41	255.1	0.81	Burnham	5	
90.49	251.1	0.76	"	3	
91.53	246.5	0.61	"	3	
92.39	245.1	0.60	"	3	
95.33	194.7	0.36	See	3	
95.62	193.6	0.13	Barnard	2	
95.74	193.1	0.20±	See	1	
96.69	179.8	0.25	"	1	
97.71	115.6	0.28	"	3	
97.76	93.6	0.22	Cogshall	1	
97.76	98.7	0.18	Boothroyd	1	
98.49	93.1	0.34	Aitken	2	
1899.52	83.8	0.38	"	3	
1900.62	74.5	0.37	"	2	
1900.83	71.6	0.44	Innes	5	

The complete measures here given are plotted to scale and after repeated trials the apparent ellipse shown in the accompanying diagram was drawn. In adopting it as the basis for a system of elements I gave more weight to the position angles than to the distances, as from its great southern declination, the star was measured under unfavorable circumstances by almost all of the observers. My own experience leads me to believe that under such conditions the position angle of a pair of this character can be measured with much greater accuracy than the distance. The major semi-axis of the ellipse was based largely upon Burnham's measures of 1888, 1891 and 1892, and Innes's recent observations. An examination of Burnham's individual night's measures in 1889 and 1890 shows that there was one quite dis-

* These measures were all taken from original sources. The references are as follows: Winlock, Searle and Peirce, *H. C. O. Annals*, Vol. 13, pt. 1; Newcomb, *Washington Observations*, 1867, p. 323; Burnham, *Memoirs R. A. S.*, Vols. XLIV and XLVII; *Publications of the Washburn Observatory*, Vol. I; *Publications of the Lick Observatory*, Vol. II; Hall, *Washington Observations*, 1888—Appendix 1; Pollock, *Results of Double Star Measures made at Sidney Observatory*, 1891; Leavenworth, *Haverford College Observatory Publications*, 1888; See, *A. J.* 349, 359, *A. N.* 3496; Barnard, *A. J.* 447; Cogshall and Boothroyd, *A. N.* 3496; Aitken, *A. N.* 3585, 3639; Innes, letter.

cordant distance measure in each year, the omission of which would reduce the mean distances for those years from 0″.81 to 0″.74 and from 0″.76 to 0″.70 respectively.

By the use of the graphical method the adopted apparent ellipse leads to the following set of elements:

P = 21.17 years.	Ω = 75°.5
T = 1900.37	*i* = 69 .4
e = 0.185	λ = 1 .4
a = 0″.565	μ = − 17 .007

Considering the condition referred to above, and the few observing notes given in the first table, these elements satisfy most of the measures within the limit of error of observation as the following table of residuals will show:

TABLE OF RESIDUALS.

Date.	$\Delta\theta$ (O − C).	$\Delta\rho$ (O − C).	Nights.	
	°	″		
1867.60	− 0.5	+ 0.02	2	Winlock
67.62	+ 15.6	——	2, 0	Searle
67.80	+ 3.2	− 0.18	2, 1	Newcomb
69.74	+ 102.5	——	1, 0	C. S. Pierce
69.74	+ 8.8	——	1, 0	Winlock
78.70	+ 4.8	− 0.05	1	Burnham
79.71	− 15.6	− 0.15±	1	"
80.62	+ 1.1	+ 0.16	2	"
81.61	− 10.0	− 0.01	2	"
86.62	+ 0.8	+ 0.13	4	Hall
86.74	+ 1.3	——	1, 0	Pollock
87.62	+ 0.6	——	5, 0	"
88.62	− 2.6	+ 0.05	6	Burnham
88.71	− 1.6	− 0.01	1	Leavenworth
89.41	− 2.0	+ 0.14	5	Burnham
90.49	− 0.9	+ 0.10	3	"
91.53	− 0.7	− 0.02	3	"
92.39	+ 2.5	+ 0.03	3	"
95.33	− 8.7	+ 0.11	3	See
95.62	− 0.1	− 0.09	2	Barnard
95.74	+ 4.3	− 0.01±	1	See
96.69	+ 36.6	+ 0.05	1	"
97.71	+ 7.2	− 0.01	3	"
97.76	− 13.7	− 0.07	1	Cogshall
97.76	− 8.6	− 0.11	1	Boothroyd
98.49	− 1.2	− 0.02	2	Aitken
99.52	+ 0.2	− 0.06	3	"
1900.62	+ 1.7	− 0.09	2	"
1900.83	+ 0.7	− 0.01	5	Innes

EPHEMERIS.

Date.	θ	ρ
	°	″
1901.62	60.0	0.42
2.62	48.4	0.31
3.62	20.0	0.22
4.62	331.8	0.20
5.62	297.3	0.29
6.62	280.9	0.40
7.62	271.8	0.51

The short ephemeris shows the predicted motion of the companion star from its present position to the one it occupied at the time of Hall's measure in 1886. There are very few observations in this portion of the ellipse—practically none in the fourth quadrant—and the ephemeris indicates that in a year or two the apparent angular motion will become rapid and the apparent distance small enough to make the pair a difficult one.

It is therefore of importance that observers favorably situated and having access to telescopes of adequate power should measure ζ Sagittarii annually during the next few years.

LICK OBSERVATORY, University of California,
December, 1900.

NOTE ON CLAIRAUT'S THEORIE DE LA FIGURE DE LA TERRE.

ASAPH HALL.

FOR POPULAR ASTRONOMY.

In *Runkle's Mathematical Monthly*, Vol. I, p. 79, Professor George R. Perkins proposed the construction of a fluid parabolic mirror of great size. His plan is to revolve a cylinder of mercury about a perpendicular axis, with a constant velocity. He shows that the upper surface of the mercury would assume the figure of a paraboloid, and hence rays of light falling on this surface, parallel to the axis of rotation, would be reflected to the focus. For objects out of the zenith of this telescope a plane mirror would have to be added.

I find in Clairaut's famous book on the figure of the Earth a solution of the same question. Clairaut employs the equation for a level surface (*surface de niveau*), or the equation for a level curve, (*courbe de niveau*). According to Huygens these equations are

$$Xdx + Ydy + Zdz = 0; \quad \text{a level surface}$$
$$Xdx + Ydy \quad\quad = 0; \quad \text{a level curve}$$

The equations express the conditions that the surface of the fluid is in equilibrium. If we take the axis of rotation for the axis of y, and a horizontal line for the axis of x, and assume that the velocity of a particle at the distance x from the axis of rotation is X, the centrifugal force is $\frac{X^2}{x}$, the force parallel to the axis of rotation will be $Y = p =$ gravity; or a constant. Hence we have

$$-\frac{X^2 \,.\, dx}{x} + p \,.\, dy = 0; \quad \text{or} \quad dy = \frac{X^2 \,.\, dx}{px};$$

for the differential equation of the level curve. We have

$$\frac{X^2}{x} = \text{centrifugal force} = \frac{4\pi^2 \,.\, x}{T^2},$$

T being the time of a revolution of the cylinder.

By substituting and integrating

$$y = \frac{2\pi^2}{pT^2} \,.\, x^2 + C$$

This is a parabolic curve, and taking the origin at the vertex $C = 0$, and the equation may be written

$$x^2 = \frac{pT^2}{2\pi^2} \,.\, y$$

The focal distance is $\frac{pT^2}{8\pi^2}$.

Clairaut says this question was solved by the celebrated Daniel Bernoulli, and that Hermann gave an incorrect solution in his Phoronomie.

The idea of Professor Perkins was that such a telescope, placed where the Moon and planets would pass near its zenith, would give such bright images that the surfaces of these bodies might be studied with advantage. The mechanical difficulties of this construction are obvious.

ASTRONOMICAL BOOKS FOR THE USE OF STUDENTS.

HERBERT A. HOWE.

Second Part.

FOR POPULAR ASTRONOMY.

In pursuance of our plan of considering under several heads the books to be described, we take up historical works first. The old histories by Bailly and Delambre, which were published respectively in the eighteenth and in the earlier years of the nineteenth centuries, we shall not describe. In the Encyclopædia Brittannica under the caption Astronomy is found an excellent summary of the astronomical knowledge of the ancients. Later, under the title of "Handbooks," will be described R. Wolf's "*Handbuch der Astronomie*," which contains a wealth of historical notes.

HISTORICAL WORKS.

Grant: History of Physical Astronomy; Robert Baldwin, publisher; pp. 637.

This great work was published in 1852, and is now out of print. But copies of it may be obtained from time to time through dealers in second-hand books. It gives scant space to the astronomy of the ancients; but it contains a vast amount of well digested and accurate information covering the period from the time of Newton to the middle of the nineteenth century. The first thirteen chapters, comprising one-third of the whole, are devoted to the history of the theory of gravitation. In the remainder of the book a topical method is followed, so that one finds the history of comets in one chapter, that of eclipses in another, etc. The style is that of a master. The more solidly one is grounded in the fundamental principles of descriptive and mathematical astronomy, the more enjoyment and profit will he reap from the reading of this monumental volume.

Clerke: A Popular History of Astronomy during the Nineteenth Century. Adam and Charles Black, publishers; pp. 500, $4.00.

Since Grant's history covers the first half of the century in an admirable manner, Miss Clerke has devoted only one hundred and forty pages to it, and has expended the major portion of her effort upon the remarkable progress which the science has made between 1850 and 1885, especial attention being given to recent researches by means of the spectroscope and photographic plate, which have yielded so rich a fruitage. Over one hundred and twenty-five pages are devoted to the Sun, seventy-five to the planets and their satellites, forty-seven to comets and twenty-nine to stars and nebulæ. The development of astrophysics during the last fifteen years of the nineteenth century was so phenomenal that one must wish that the gifted author of this work might add a few chapters, bringing her history down to the close of the century. The thoroughness of her work and the charm of her style would ensure a multitude of readers.

Lebon: Histoire Abrégeé de l'Astronomie; Gauthier-Villars et Fils, publishers; 8 francs.

To the period prior to the middle of the sixteenth century but eighteen pages are devoted, so that only a birds-eye view is obtained. The next three hundred years, beginning with Copernicus and ending with Bessel, from what the author calls the

modern period; about half the book treats of the last fifty years with considerable fulness. A biographical and bibliographical appendix contains much of interest and value. There are sixteen full page portraits of celebrated astronomers. The book is split up into a large number of sections each of which usually contains a statement of the work of one astronomer only. There is a noteworthy preponderance of French astronomers and dearth of Americans. Several of the statements about American astronomy are inaccurate.

Tannery: Researches sur l'Histoire de l'Astronomie Ancienne; Gauthier-Villars et Fils, publishers; pp. 370.

The author confines himself chiefly to a study of the Almagest, which he prefaces by three chapters on Greek astronomy and astrology anterior to the time of Ptolemy. He believes that too much honor has hitherto been given to Hipparchus, who has been credited with several researches that were really the work of his predecessors. The book is intended for specialists in historical research, rather than for the general reader.

Berry: A Short History of Astronomy; John Murray, publisher; pp. 444; 5s 6d.

The first chapter is supposed to be devoted to primitive astronomy, but contains very little on that subject. Chapter II gives a just estimate of Greek astronomy. The next ten chapters, which comprise nearly three hundred pages, are devoted to astronomical progress during the middle ages and beyond, to the close of the eighteenth century. Here we find much matter about Copernicus, Kepler, Galileo, etc., with a good deal of which the reader is quite likely to be familiar already. Only fifty-five pages are devoted to the astronomy of the nineteenth century. The book is well indexed and contains beautiful illustrations, many of which are portraits of noted astronomers.

Fison: Recent Advances in Astronomy; Blackie and Son, publishers; pp. 242; 2s, 6d.

Here are collected a series of essays clearly and attractively written, which deal with a few of the most interesting astronomical problems of the day. The fundamental principles of astronomical spectroscopy are well elucidated, but late discoveries and investigations with the spectroscope are not given. The mysteries of star evolution and stellar distribution are well handled. A very satisfactory chapter is the one in which the author discusses recent observations of, and theories about, the planet Mars.

Maunder: The Royal Observatory Greenwich; The Religious Tract Society, publishers; pp.320; 5s.

No one who is interested in astronomy can begin this charming book without finishing it, time permitting. In it Mr. Maunder is at his best. The history of the Greenwich Observatory is coextensive with that of modern astronomy, for the institution was founded in Newton's day. It is at present pursuing so many lines of research that its activities cover nearly all the principal kinds of astronomical observations. The book therefore gives a good view of present day methods of work. The first four chapters are devoted to an historical sketch from Flamsteed to Christie, the present astronomer royal; the remaining nine describe the work now going on. The publishers have done their part exceedingly well, and the result is a volume which is at once a delight to the eye and a feast to the mind.

Blake: Astronomical Myths: Macmillan & Co., publishers; pp. 431; $2.00.

Flammarion's History of the Heavens is the work upon which this one has been founded. There are fifteen chapters which contain much matter about the beginnings of astronomy and geography, which it is not easy to lay one's hand on elsewhere. Some of the chapter headings are "Astronomy of the Celts," "Origin of the Constellations," "The Pleiades," "Nature and Structure of the Heavens according to the Ancients," "The Terrestrial World of the Ancients," and "Legendary Worlds of the Middle Ages." The title "Astronomical Myths," is rather unfortunate, since the author deals with facts of great interest.

Allen: Star Names and their Meanings; G. E. Stechert, publisher; pp. 563; $5.00.

The title of this work might lead one to suppose that it was full of philological discussions, because there is much opportunity for writing of that sort about star names. Instead of this we find exceedingly clear and interesting statements of the results of the author's laborious investigations, the processes being kept in the background. Mr. Allen has no hare-brained theories to exploit, and simply gives the results of scholarly inquiry. After devoting about thirty pages to a general and historical description of the constellations, including the special divisions called the "Solar Zodiac" and the "Lunar Mansions," the author discusses each constellation in detail, their arrangement being alphabetical. Under a given constellation he gives the different names by which it has been designated, its mythological history, its representa-

tions on maps, and the allusions to it in literature. After the general description of a particular constellation one finds a discussion of each of its most notable stars, in which, in addition to literary information, there is a statement of the facts concerning its parallaxes, proper motion, etc. To Sirius, for example, ten pages are devoted. When the last star-group (Vulpecula) has been handled, there is a chapter on "The Galaxy," followed by exhaustive general and special indexes.

This monumental work of Mr. Allen's, apart from its scientific value, will be found exceedingly helpful to teachers in making constellation study interesting. It is printed by the DeVinne Press, which is a guarantee of the excellence of its mechanical execution.

Biographical Works.

One may find biographical sketches in the German language, of all the most prominent of the world's astronomers. One has only to look in any German catalogue of astronomical books, under the titles Copernicus, Kepler, etc., to find such biographies. We shall mention but a few works of moderate compass, written in our own tongue.

Brewster: The Martyrs of Science; Chatto and Windus, publishers; pp. 248; 4s, 6d.

Sir David Brewster has given, under this title, short and interesting sketches of the lives of Galileo, Tycho Brahe and Kepler.

Dreyer: Tycho Brahe, a Picture of Scientific Life and Work in the Sixteenth Century; Adam and Chas. Black, publishers; pp. 405; $3.50.

Dr. Dreyer's book furnishes not only a readable and trustworthy account (drawn from original sources) of Tycho's life, but also gives an excellent representation of the conditions under which scientists labored in the sixteenth century. Quite a little space, first and last, is given to the astrological fancies of the age.

Ball: Great Astronomers; Isbister & Co., publishers; pp. 372; 7s, 6d.

In this book are sketched the lives of eighteen astronomers, from Ptolemy to Adams, the author's endeavor being to enable the reader to realize each man's character and surroundings. The biographies are arranged chronologically; after Kepler all are Englishmen, except Laplace and Le Verrier. There are many pictures of instruments and buildings of historic interest.

Lodge: Pioneers of Science; Macmillan & Co., publishers; pp. 404; $2.50.

Under this title the author has written a series of bright papers on astronomical progress from the days of Copernicus to the discovery of Neptune. The first half of the book contains biographies of Copernicus, Tycho, Kepler, Galileo, Descartes and Newton. The next hundred pages are semi-biographical in nature, and treat of the discovery of the velocity of light, the stability of the solar system, the distances and motions of the fixed stars, together with the discovery of the asteroids and of Neptune. The last two chapters contain an admirable explanation of the tides and tidal evolution.

Clerke: The Herschels and Modern Astronomy; Macmillan & Co., publishers; pp. 224; $1.25.

Miss Clerke has here given in her usual fascinating style a brief account of the lives and work of Sir William, Sir John and Miss Caroline, and has devoted one chapter to the influence of Wm. Herschel's career upon modern astronomy. Her materials were largely obtained from original sources, but she gives acknowledgement to Mrs. John Herschel's "Memoir of Caroline Herschel" (London, 1876), and to Professor Holden's "Herschel, his Life and Work," (London, 1881).

Mitchel: Ormsby Macknight Mitchel, Astronomer and General; Houghton Mifflin & Co., publishers; pp. 392; $2.00.

Professor Mitchel was the founder of the Cincinnati Observatory, and carried that enterprise to completion in a manner quite as marvelous as a romance. "Old Stars" was a unique figure among American astronomers, and accomplished by the sheer force of his oratorical powers, what would be impossible for one less wonderfully gifted. In the first part of this biography, which has been written by his son, we have a charming picture of the man, and of his astronomical endeavors. The second part of the biography is devoted to his life as a General. The entire account has much of the interest of an autobiography, since Professor Mitchel's letters, which were quite as fascinating as his lectures, are quoted in abundance.

Holden: Memorials of Wm. C. Bond and Geo. P. Bond; C. A. Murdock & Co., publishers; pp. 291; $2.00.

We find in this book a history of the struggles of two gifted and thoroughly admirable men, in establishing and directing the Harvard Observatory. There is much interesting correspondence between notable astronomers. One gets glimpses of the state of

practical astronomy in Europe fifty years ago from G. P. Bond's letters describing his visits to the principal foreign observatories. There is lasting inspiration to be derived from the revelation of the characters of these noblemen of science.

A NEW ECLIPSE PHENOMENON.*

J. F. LANNEAU.

FOR POPULAR ASTRONOMY.

During the eclipse last May there was observed at Wake Forest College, N. C., a peculiar and suggestive phenomenon which, as far as I know, has been noted no where else, nor on any previous occasion.

I hope it will be studied in Sumatra by observers of the great eclipse of next May.

Last May a trivial addition to our outfit for the various observations made, was a number of neatly prepared smoked glasses for naked-eye views of the progress of the eclipse. Each of these eye protectors consisted of a piece of clear glass put over the smoked surface of a like piece, the two held together securely by paper pasted along their edges.

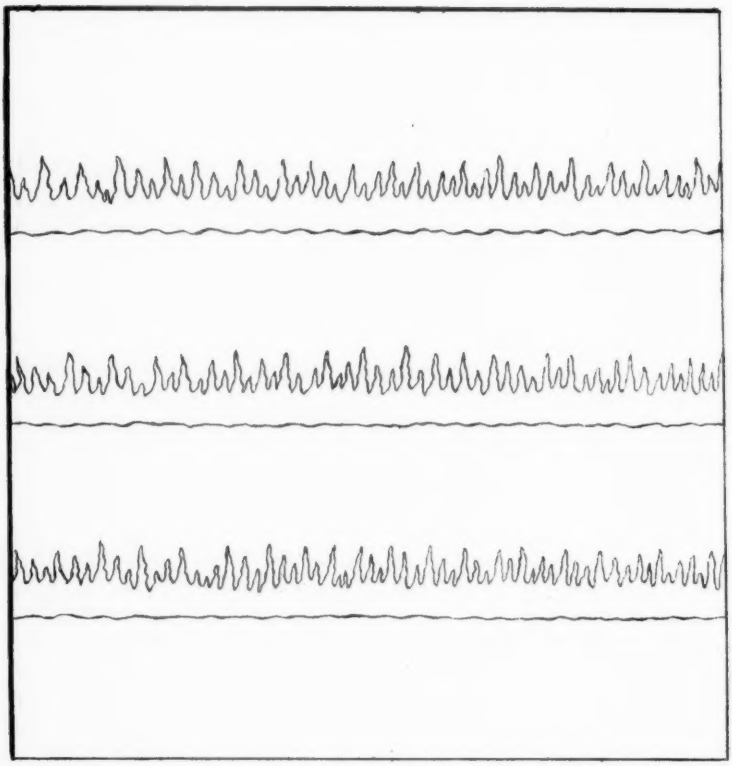
These simple glasses made an unexpected revelation.

Soon after first contact, but more especially for five or ten minutes before totality, when a smoked glass was held somewhat toward the Sun, and tilting westward, there was seen on its nearer surface, as in a dull mirror, three fairly distinct, whitish or greyish bands extending horizontally across the glass. The bands were each about a quarter of an inch wide. Below them was a fourth band which was not distinct. The upper edge of each band was uneven if not wavy. The lower part of each presented a ragged outline—a series of pendent tongues variously pointed and differing in length, breadth and contour. Each band looked something like the familiar mirrored band of "manometric flames" produced by sound vibrations; only fainter, less regular, and also *inverted*, that is, the "tongues" downward.

These bands appeared to be stationary on the glass, but changed in width as the glass was more or less tilted. When, however, the glass was steadied against some support, say a tree, the bands moved slowly *downward*, toward the lower edge of the glass. Unfortunately, no attention was paid to either

* Credit for the facts observed is due to several student assistants, especially to Mr. J. Q. Adams who first called my attention to them.

shadow or glass *during* totality. In that eventful minute (only 58 sec. here), who but the faithful photographer and the scrupu-



REFLECTION BANDS ON SMOKED GLASS.

lous contact-noter could forego feasting his eyes on the marvellous coronal splendors!

The phenomenon which, in the main, has now been described was characterized in the outset as peculiar and suggestive.

It suggests some connection with that curious complication known as *shadow bands*.

By way of distinction the "bands" in the phenomenon described may be termed *reflection bands*.

Since Goldschmidt's observation in 1820, some attention has been given to the parallel shadow bands which just before and after totality flit across the ground. They vary at different

eclipses in many respects,—in distinctness, width, direction and rapidity. On one occasion barely perceptible, on another they are quite distinct. At one eclipse they are about a foot broad with light intervals of several feet in breadth; at another, as in the eclipse last May, shadow bands and intervals are only the width of a lead pencil. They may flit by with the moderate speed of a pedestrian, or with the swiftness of a bicycle. At any eclipse, before totality, the shadow bands range in one direction, after totality in another.

They are seen only when the Moon nearly obscures the Sun; that is, always in the shadow cone's edge. Nevertheless, some think they are no part of the lunar shadow. Some hold that they are of atmospheric origin. Indeed the shadow bands are an intricate puzzle.

But the *reflection bands*, as I have termed them, seem to be the Ariadne clue to this shadow band maze.

For a *total* eclipse, the cone of shadow tapers from the Moon to a point more or less beyond its dark section, or shadow spot, on the Earth's surface. Now allow an assumption, a seeming arbitrary assumption. Later on we may reasonably decide for or against its acceptance.

Assume about the shadow cone proper, thin envelopes of light and shade in turn, capping, so to speak, the residual dark cone.

This shadow cone *lowers* from the west toward the observer as totality approaches. Lowering, and nearing the observer, the envelopes, dark and light in succession, meet the ground obviously in a rapidly broadening area (broadening north and south) and thus *stripe* the ground with *bands* of light and shade, "shadow bands," trending mainly westward; and *seeming* to flit either northward or southward as the observer may judge.

After totality, the envelopes of the westward side of the cone meet the ground in a *narrowing* area and with an altered trend, —altered by the swing of the cone. Hence, the changed direction of the shadow bands after totality, and the seeming reversal of their flitting. As observed here last May, the shadow bands before totality ranged 5¼° north of west; and after totality, 32¼° south of west. Judgments differed as to their lateral motion.

Once more consider the Moon's shadow cone as it lowers from the west upon the observer. Of the assumed envelopes on its under side, now nearing the observer, some of the light strata should be imaged as *whitish bands horizontally* across the glass. This, *seemingly*, was the origin of the "reflection bands" noted last May.

Again, as the shadow cone lowers gradually, reflections of light strata in a glass should sensibly lower. The "reflection bands" observed here *were seen* to move slowly down the glass.

So far, the facts appear to warrant the assumption,—the hypothesis of light and shade envelopes about the lunar shadow cone.

May we not concede that *some such* envelopes must be formed by the well known action of light when it grazes the edge of an opaque object,—its diffraction,—or diffraction modified by lunar conditions?

Doubtless, all around the Moon, grazing its ring of contact with the Sun's tangent light cone, curved sheets of diffracted, or pseudo-diffracted, light slant inward and converge to points successively short of the shadow cone's apex—thus forming conical envelopes of alternate light and shade.

If it were a smooth sphere casting the shadow cone, a section of the cone would doubtless show a series of concentric rings, light and dark in turn.

But the Moon is no smooth sphere. Ragged-rimmed, crater-like upheavals, and mountain ranges, and peaks innumerable crowd the visible lunar surface.

Necessarily, then, the Moon's rough ring of contact with the tangent light cone outlines, in profile, the semblance of a Titanic circular saw with mismatched, jagged teeth. These salient points all around the contact ring certainly give to the shadow cone and to its envelopes, something like sharp *flutings*. And certainly these flutings crowd together and sharpen as they converge beyond the observer towards the relatively not distant apex of the shadow.

Clearly then, a cross-section of cone and envelopes west of the observer, would outline concentric light bands with small, jagged teeth, or tongues, all *pointing outward*.

With this structure of the shadow cone, it is plain that *before* totality light envelopes along the *under* part of the cone must image in a glass facing the apex something like "manometric" reflection bands with *downward* tongues: *such as were seen here last May*.

So too, towards the end of totality reflection bands should be formed by light from the envelopes along the *upper* or westward side of the shadow cone, with tongues pointing *upward*.

This simple *test* of the envelope hypothesis remains to be applied.

BOARD OF VISITORS FOR THE UNITED STATES NAVAL OBSERVATORY.

W. W. PAYNE.

In 1899, June 30, a Board of Visitors consisting of Hon. Wm. E. Chandler, chairman, Hon. A. G. Dayton, Professors E. C. Pickering, Harvard College Observatory, George E. Hale, Yerkes Observatory and George C. Comstock, Washburn Observatory was appointed for the purpose of making an examination of the United States Naval Observatory.

John D. Long Secretary of the Navy, sent to the chairman a memorandum respecting the functions of the proposed Board of Visitors to the Naval Observatory, which contained suggestions that the Board were to have in mind while making the examination.

It said to the Board, you are "authorized to examine the equipment and working of all parts of the Naval Observatory, and to make any suggestions which may seem desirable for improving the scope and efficiency thereof," but in so doing the Secretary said certain facts should be borne in mind, the substance of which follows:

(1). The most important astronomical duty of the Government is the publication of the Nautical Almanac for the use of navigators and the guidance of astronomers in the varied work they are seeking to do. To this end continuous observations by the meridian circle of the Sun, Moon, planets and stars are absolutely necessary. It is desirable to observe the satellites to the planets in order to determine the masses of their primaries. On this account it was advised that the question of procuring a large heliometer for the Naval Observatory be considered.

(2). "As a secondary object, the Naval Observatory has always found it possible to observe asteroids, comets and double stars, and it has recently obtained spectroscopic apparatus for the investigation of the motions of stars in the line of sight." The Secretary suggests, "that the Board might well consider how far such secondary work should be extended. Also whether or not it is desirable to obtain a 13-inch photographic telescope for the purpose of mapping more or less extended portions of the of the heavens."

(3). The testing of chronometers. The processes employed at the Naval Observatory have gradually grown up there, and, as

there is very little precedent for most of them, the Secretary said the opinion of the Board on their scope and usefulness would be valuable.

(4). Concerning magnetic observations, the disturbance from the electric street railway near by, and the desirability of continuing these observations which seem useful; if so, also, some means to remedy existing hinderances.

(5). The serious defect in the present management of the Naval Observatory is the backwardness of its publications which has been caused by unavoidable circumstances, and which will not recur in the future. The work on the reduction of the zone stars in coöperation with the German Astronomical Society has fallen behind because of the limited number of computers in the staff. If the work is continued it is thought that publications of each annual volume can be completed within eighteen months after the last observation for each one is made. As the removal to the new Observatory will probably mark the beginning of a new series of publications, the visiting Board is asked to consider whether or not any changes are desirable in the forms adopted for the printing of the observations.

1899, Oct. 2, the Board of Visitors made their report to the Secretary of the Navy. It included seven subdivisions: (1) Recommendations of the Board of Visitors; (2) Circumstances leading to the appointment of the Board of Visitors; (3) Cost of the Observatory; (4) Comparison with other observatories; (5) Present condition and methods of Observatory work and the delay of printing its results; (6) Historical sketch of the Observatory; (7) Minutes of the proceedings of the Board of Visitors; (8) Appendix.

A full statement containing the substance of this report appeared in POPULAR ASTRONOMY, Vol. 7, page 459. Brief reviews of this important paper appeared in other periodicals and knowledge of it has certainly been quite widely circulated; for this reason a brief synopsis of it, even, seems scarcely necessary to remind our readers of its contents. A few references to the most important recommendations, however, may not be amiss for the purpose of connecting some articles that have recently appeared in print with the report to which they refer.

1. The first point made in the report was in reference to the propriety of keeping a national astronomical Observatory under the management of the Navy department of the Government. Such a control for a national astronomical Observatory has seemed to many astronomers both illogical and undesirable.

But in view of a lack of a department of science and industries in the present organization of the Government, the report favored the continuance of the present method of control with some important modifications.

2. In reference to the organization of the Observatory under naval administration, the report disapproved of those parts of the proposed organization which required the establishment of a formal Observatory council with nominal functions which, by omission, practically abolished the office of astronomical director. No great Observatory is managed in that way.

3. If the Observatory, as a shore station, is to do work for the Navy and be under the command of a line officer, the report recommends that the astronomical staff of the Naval Observatory shall consist of the astronomical director, four astronomers, three assistant astronomers, and such computers and other minor officers as shall be provided by law. The director and astronomers shall be taken from civil life and be appointed by the President with the advice and consent of the Senate and hold their offices until successors are appointed.

4. The report favored making a distinct bureau for the Nautical Almanac, because of the amount of work required for it. The appointment of the director of the Nautical Almanac should be in the same way as that of the director of the Observatory.

5. On account of long continued and forcibly urged criticism against the administration of the Naval Observatory, covering almost the entire period of its existence, this report recommended the establishment of a permanent Board of Visitors which should consist of nine persons; six to be astronomers of high professional standing, and three to be eminent citizens of the United States. The members of this Board should serve without compensation but their expenses should be paid while on duty. The duties of this permanent Board of Visitors are defined and their term of office indicated.

6. The report recommended the following schedule of salaries, with reasons for the same:

Astronomical Director	$6,000	Fourth Astronomer	$2,800
Director of Nautical Almanac	5,000	First Assistant	2,400
First Astronomer	4,000	Second "	2,200
Second "	3,600	Third "	2,000
Third "	3,200		

In the report of the Superintendent of the United States Naval Observatory, Captain C. H. Davis, for the fiscal year ending June

30, 1900, very full reference is made to this report of the Board of Visitors on pages 6 to 13 inclusive. In brief the following points are made:

1. The report is in the nature of an attack on the Observatory which is made to appear in an odious light before people who have any interest in its work. This was done by a Board of Visitors three members of which are astronomers whose appointment was concurred in by the Superintendent "because they were already the members of a self-constituted committee to conduct a gratuitous investigation of the Observatory, and known to be inspired by a hostility to its organization."

2. Referring to the memorandum of the Secretary of the Navy, the substance of which is given above, the Superintendent claims that "not one of the subjects proposed in the memorandum received the attention of the Board or was even mentioned by it. The whole report was taken up with the proposed reorganization, a subject which it had not been asked to consider at all, and for which it could only find a general authorization in the concluding paragraph of the Department letter."

3. Comparison of the cost of maintaining Greenwich, Harvard and the U. S. Naval Observatories, the purpose being to show economy in the present kind of administration at the Naval Observatory.

4. The delay in printing the Naval Observatory work is discussed at length, in very definite language, placing the responsibility of delays in printing not on the administration of the Observatory but rather on account of the limited force in the Observatory staff provided for the amount of work to be done.

5. On the whole the Superintendent says measures proposed by the Board of Visitors are "preposterous" and "only ridiculous."

We have aimed to give enough of the report of the Board of Visitors and the answer made to the same by the Superintendent of the U. S. Naval Observatory, Captain C. H. Davis, to give our readers a glimpse at the present situation of affairs, in respect to the contest that has been going on since the Observatory has had any prominence in its early history.

In recent numbers of *Science* much is said editorially in double-leaded articles in answer to this very remarkable paper claiming to be a "criticism" of the Board's report. We wonder that *Science* should have deemed it necessary or even desirable to give such a full, courteous, and yet politely sarcastic reply to a bom-

bastic tirade of an official Captain of the navy, in answer to to a so-called "criticism" of something.

It rather seems to us that the brave Captain has just returned from some foraging expedition, in which his courage failed to secure enough for his breakfast, and he is out of patience about it; or, may be, he has been court marshaled and he does not like the way his case has been handled. The Captain is evidently out of his place in trying to discuss the needs of the Naval Observatory.

This so-called "criticism" is certainly enough to convince anybody that there is need of a change in the plan of administration of the Naval Observatory so far as the appointment of the Superintendent is concerned.

Other parts of this report which show the work of members of the staff, as presented over their names, are commendable, and space would be given here to a full review if it were now at our command. It will be noticed elsewhere.

AN ABSTRACT OF PAPER ON STARS IN COMA BERENICES.

W. C. KRETZ.

FOR POPULAR ASTRONOMY.

"*The Positions and Proper Motions of the Principal Stars in the Cluster of Coma Berenices, as Deduced from Measurements of the Rutherfurd Photographs, by Walter C. Kretz.*"—*Contributions from the Observatory of Columbia University, No. 16* (*Annals of the N. Y. Academy of Sciences, Vol. XII, pp. 341-478*).—In the years 1870, 1875, and 1876 Rutherfurd took with his 13-inch object glass and correcting lens a series of fourteen photographs of the cluster in the constellation Coma Berenices. At his death they went into the possession of the Columbia University Observatory, where they have been preserved. No work was done on them until the spring of 1897, when the author, then scholar in astronomy at Columbia, undertook, at the suggestion of Professor Jacoby, the task of measuring and reducing these plates. An excellent straight scale Repsold measuring machine belonging to the Observatory was available for this purpose. A very accurate determination of the division errors of the scale, and of the non periodic errors of the micrometer screw had previously been made.

The machine is adapted both for measuring rectangular and polar coördinates. The former method was selected in the present case, as in all of Rutherfurd's photographs, there are, on

every plate, two impressions of each star, about a minute of arc apart in right ascension. These were obtained by exposing the plate for six minutes, then stopping the driving clock of the telescope for a few seconds, and then starting it again and exposing again for six minutes. A third image, or "trail," of the brighter stars, was obtained in the same way, except that the clock was stopped for a longer time than in the previous case. In measuring the plates, the trail was used only for orientation, while observations were made on each of the other images. A full set always consisted of two readings on the East Image, two readings on the scale; two readings on the West Image, and two readings on the scale. All the stars having been thus observed in any given order, the process was repeated, the order of the stars being inverted however. Two observers being always engaged on the work, care was taken to have each observer read all the stars. The temperature, runs of the micrometer microscope, and reading of a graduated circle on the plate holder were recorded before and after each day's work which consisted in a full set of observations on all stars on any plate as described above. On the next working day, the plate was rotated through 90°, and the process repeated. If then the first set of measures gave differences in right ascension, the second position would give differences in declination. To eliminate personality, and to increase the accuracy, measures were also taken with the plate 180° and 270°, respectively, from its original position.

Evidently these measures, when corrected for division errors of the scale, for runs, and for screw errors, give the differences in right ascension and in declination of the stars on the plates in terms of scale divisions. If, then, we select any point on the plate, whose position with respect to the scale is known, as origin, we can obtain the rectangular co-ordinates of all the stars with respect to that point. Correcting now these co-ordinates for rotation errors (due to the fact that the plate could not be turned through exactly 90°, although the amount of error could be accurately determined) and taking the means of the co-ordinates obtained from positions of the plates 180° apart we obtain finally the "corrected co-ordinates" of the stars.

These corrected co-ordinates must now be transformed into angular measure. Evidently certain corrections must be applied. In the first place a photograph being a projection on a plane of part of the heavens, the so-called "transformation correction" must be added to each measured co-ordinate so as to obtain spherical co-ordinates. The values of these corrections were

computed by means of formulæ given by Professor Jacoby in his review of "Donner, Determination des Constants, etc." *Vierteljahrschrift* for 1895, p. 114. When thus obtained, they eliminate certain inaccuracies caused by the method employed in reducing the measured into celestial co-ordinates; they are also constant for all the plates, and are hence best applied to the final means after all the calculations described below have been made. Besides the errors in the co-ordinates to which attention has just been called, they are affected by refraction, precession, nutation, and aberration. The former was eliminated by means of certain formulæ published by Professor Jacoby in the *Astronomical Journal*, No. 387. The latter three, as can be shown, are eliminated when the plate constants are obtained by the method now to be described.

It is evident that, in order to change the measured into celestial co-ordinates four quantities must be known. They are: The value in seconds of arc of one division of the scale, i. e. the scale-value; the small angle made by the axes of reference on the plate, with the axes of reference in the celestial sphere, caused by inaccurate setting of the plate in the holder of the measuring machine (known as the Orientation Correction); and the error in right ascension and in declination of the assumed position of the origin, which was taken to coincide with a certain star on the plates. The values of these constants can be obtained by the method of least squares, provided the actual positions of several stars on the plates are accurately known. Such stars are called "Standards." Their positions were deduced from all available meridian observations as published in catalogues. Thirty catalogues, comprising all those entitled to any confidence mentioned in Knobel's memoir (in *Mem. Roy. Ast. Soc.* Vol. 43, p. 1) besides all modern ones, and all published "Annual Results" were used for this purpose. From them the final positions reduced to the system of the "Fundamental Catalog der Astronomischen Gesellschaft" were obtained for 1875. The method employed was similar to that used by Professor Safford in his "Catalogue of 2018 Stars." A full discussion of all necessary corrections, and of the formulæ for reduction, will be found in Part I of the paper under consideration. There also is given a list and discussion of the catalogues used in the investigation. I need not, therefore, enter further on this subject.

Assuming, then, the positions of the standards as known, we can obtain their actual distances in right ascension and in declination from the origin of the plate-measures. These distances

should equal, within the limit of error of the observations, the corresponding co-ordinates obtained from the plates, where the latter are reduced to angular measure by means of an assumed scale-value, are corrected for refraction and have the transformation corrections applied. Any deviation is due to the causes which give rise to the plate constants, and which have been mentioned above. The values of these constants can hence be obtained by the method of least squares. Knowing them, as also the refraction factors and the transformation corrections, it is then an easy matter to calculate the final spherical co-ordinates of all the stars on the plates as obtained from the photographic measures. A full discussion of all these methods, as well as the results and the conclusions to which they lead will be found in Part II, Sect.'s III and IV of the paper under consideration.

On page 477 of the same paper is given a catalogue of 24 stars of the cluster in Coma Berenices, with proper motions as far as possible, for the epoch 1875. These positions depend solely on the photographic measures and on the positions of the standards deduced as explained above from catalogue positions and are hence entitled to a high degree of confidence. This claim is borne out by the size of the probable errors, which is, for a position depending on fourteen plates:

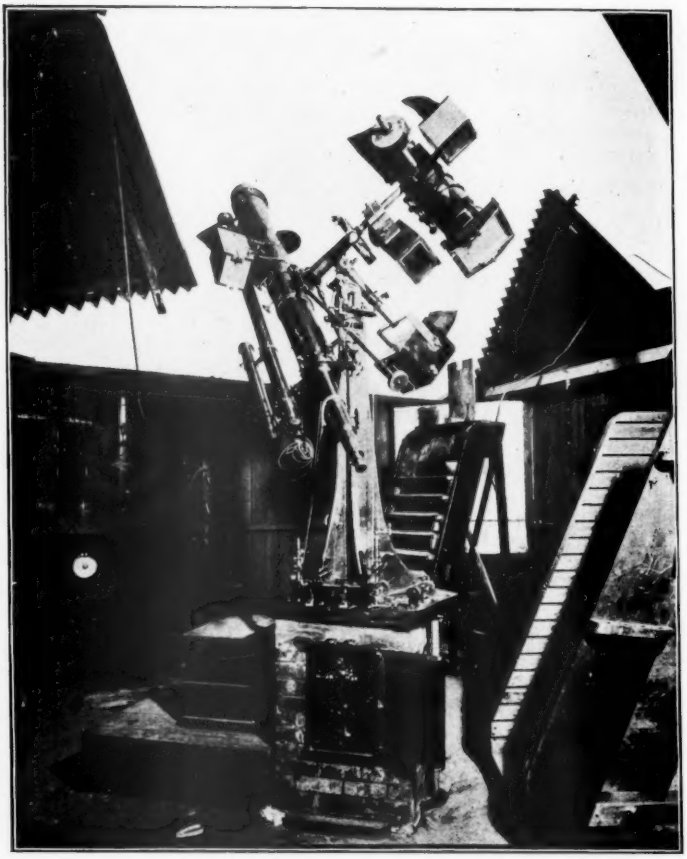
$$\text{In } \alpha \pm 0''.025$$
$$\text{In } \delta \pm 0\ .016$$

and for a position depending on a single plate:

$$\text{In } \alpha \pm 0''.094$$
$$\text{In } \delta \pm 0\ .060$$

the probable error in right ascension being in both cases given in seconds of arc of a parallel of declination through the center of the plate. The appreciably larger value of the probable error in right ascension is due to the fact that measures in that co-ordinate on the plates are less accurate than measures in declination owing to the elongation of the star images caused by defective working of Rutherfurd's driving clock. The relative reliability of catalogue right ascensions and declinations evidently does not enter into consideration, as the constants of the plates are obtained from a least square solution introducing both co-ordinates. A discussion of these results will be found in Part II, Sect. IV of the paper under consideration.

PLATE II.



C. A. Post's Equatorial (6-inch) Arranged for Meteor Photography. Bayport, L. I., N. Y.

OBSERVATIONS OF NOVEMBER METEORS, 1898, 1899 AND 1900.

J. K. REES.

FOR POPULAR ASTRONOMY.

On account of the sale of the Observatory site in 1898, and the consequent tearing down of the Observatory, the Rutherfurd equatorial (13 inches aperture) and all other instruments were placed in the basement of Fayerweather Hall at the new site.

There the instruments remain for want of funds to purchase new grounds and for putting up a new Observatory building. Hence, lacking mounted instruments of our own, it seemed to me that the importance of observing for the expected Leonid shower in November, 1899 was so great that I decided to secure the aid of other observatories and numerous observers. No funds being in the Observatory treasury for this purpose, I was fortunate in securing the financial aid of J. H. Ladew, Esq., and F. Augustus Schermerhorn, Esq., of New York City. Professor E. C. Pickering of Harvard College Observatory kindly sent me maps and blanks for recording.

Colonel P. S. Michie of West Point Military Academy most cheerfully placed the Observatory on Putnam Hill at my disposal; and Lieutenant Crabbs, in charge of the Observatory, was enthusiastic in giving aid in every way. The instrument maker, Mr. Grunow was also ready to assist.

Mr. Charles A. Post of New York City, who has an excellent Observatory at Bayport, Long Island, placed his Observatory, his instruments, his home and himself at my service.

Some twenty-five students, and our computing staff, of young ladies assisted by Miss Proctor, offered to watch, count and record the meteors in New York City.

Mr. Lembke, of Gall & Lembke, opticians, and Mr. L. J. R. Holst, of the firm of C. P. Goerz, manufacturing optician, loaned me apparatus, and also arranged to photograph the shower in Brooklyn with their own instruments.

The results of all the observations were important mainly in their negative character. However, it seems best in justice to all to place on record the work done or attempted.

WEST POINT, United States Military Academy Observatory.
The party was in charge of Dr. S. A. Mitchell of Columbia Ob-

servatory, who was ably assisted by Lieutenant Crabbs and Mr. Grunow, the instrument maker. Dr. Mitchell spent a week at West Point arranging details and on watch for the meteors. During the last three days (November 14th, 15th and 16th, 1899) further assistance was rendered by two graduate students of Columbia (in the course of astronomy), Messrs. G. N. Bauer and P. W. Jenkins.

To the 12-inch equatorial tube were clamped:

(1). A Rowland concave grating near the declination axis, arranged to photograph the spectrum of a meteor. Focal length of mirror, 19 inches. Ruled surface, 2 in. x 5¾ in., 7219 lines per inch.

(2). Camera with Voigtlander lens—5 in. aperture and 17 in. focal length (back focus).

(3). Camera with a Goerz double anastigmat lens of 2 in. aperture and 9 in. focal length (back focus).

Numbers (2) and (3) were fastened near the object glass. No photographs were taken. The observers made the appended record of meteors seen.

NEW YORK CITY. The observers at Columbia University and elsewhere in New York City were under the special charge of Professor Jacoby. The records made are appended:

BAYPORT, Long Island. C. A. Post's Observatory.

Latitude	40°	43′	52″.5
Longitude west of Greenwich	73	3	1 .9

After conference with Dr. Elkin, of the Yale Observatory, which is about 40 miles almost due north of Bayport, I arranged with Mr. Post to attempt to catch on our plates some meteor which Dr. Elkin might also photograph. Our pointings for this, were at the radiant. Through the aid of the late Mr. James Hamblet, in charge of the Western Union Time System, we were enabled to receive at the Bayport telegraph office every day at about 5 P. M., time signals which provided us with accurately determined errors of our chronometers. Mr. Hamblet cheerfully assisted in many ways and was employed by Mr. Post to overhaul and clean the driving clock of the equatorial preparatory to the work.

The apparatus employed is given in the following table:

Instrument.	Aperture.	Focal Length.
Equatorial Telescope	6 in.	90 in.
Photographic lens	6 "	80 "
Guiding telescope	3 "	84 "

Instrument and Lens.	No.	Aperture.	Equivalent Focus.
Willard photo. portrait doublet	5	5½ in.	23 in.
Goerz wide angle double anastigmatic	3	1½ "	10½ "
Anthony portrait lens	4	3 "	13½ "
Voightlander portrait	2	3 "	10 "
Darlot portrait	1	1½ "	6½ "

These five cameras were mounted as shown in the illustration (Plate 1).

Watch was maintained during the nights of 13th, 14th, 15th, 16th and 17th. Twenty photographs were taken on the night of November 15th. Careful examination of these plates show only one meteor trail taken by the Goerz lens when pointed at Procyon between $16^h\ 9^m\ 30^s$ and $16^h\ 40^m\ 44^s$, Standard mean time (75th meridian). This plate is now in the hands of Dr. Elkin of the Yale Observatory.*

The watchers' record of meteors observed is appended. There is also appended the record made by Mr. M. H. Parker on Nov. 14, 1898, at Mr. Post's Observatory at Bayport, L. I. In November, 1900, Mr. Post again placed his Observatory in my hands and as usual did most of the work. No photographs were obtained.

Observers:—Misses Proctor, Tarbox, Harpham, N. Y. City, 141 West 47th Street.

Latitude, 40° 48′. Longitude, $4^h\ 56^m$. Condition of Sky, Clear.

Date.	Frequency of Meteors.			Individual Meteors.			
	Time of Beginning.	Time of Ending.	No. of Meteors.	Time	Class.	Magnitude.	Color.
1899.	h	h					
Nov. 15	12:55	14:00	8	Eastern	Leonid		
	14:00	15:00	7		"		
	15:00	16:00	18		"		
	16:00	17:00	17		"		
	17:00	18:00	18		"		
			68	h	"		
				16:25	"	— 2	Greenish

* Dr. Elkin writes, January 7th, 1901, that the trail has been measured and located, giving N = 111° 1′.1; I = 32° 32′.5; N = Node; I = Inclination of Trail on Equator of 1875.

Notes on the observations by Miss Proctor. Moonlight so bright needed no other light to record observations.

Time.	Train.	Direction.	Mag.	Col.
12.55		Passed between Regulus and Gamma Leonis.		
1.01		Southwest.		
1.20		Towards Gt. Dipper from Sickle.		
1.30		Sky hazy in vicinity of Leo.		
1.32	5°	Southwest from Sickle.		
1.42		Leonid.		
1.46		Leonid, passed close to Regulus.		
	5°	Between stars of Dipper. Leonid.		
1.57		From middle of Sickle.		
2.00		Between Regulus and Iota Hydrae. Sky perfectly clear.		
2.15		Between Regulus and Iota Hydrae. Very swift.		
2.24		Between Lynx and Leo.		
2.25		Near Delta in Leo.		
2.27		Leonid passed near Big Dipper.		
2.42		Between Theta and Delta in Leo.		
2.50		Leonid in direction of Dipper.		
3.05		Leonid in direction of Denebola.		
3.15		From radiant through Regulus.		
"		Between Mu and Epsilon Leonis.		
3.18		Epsilon Leonis.		
3.23		Leonid passed near Procyon.		
3.25		Leonid in direction of Procyon.		
3.27	20°	Leonid passed Procyon and Sirius.		
3.29	20°	Leonid passed through handle of Dipper.		bl. y.
3.33		Direction of Big Dipper.		
3.36	35°	West through Gemini. Leonid.	Very bright.	
3.37		From Leo through Iota Hydrae.		
3.42		From radiant towards the Pointers.		
3.43		Passed through radiant and Denebola.		
"		" " " " "	Sirius.	
3.48		Leonid toward Regulus.		
3.53	20°	Leonid, above Pointers towards Polo.	Procyon.	
3.55	15°	From radiant direction of Pointers, visible two seconds.	Procyon.	
3.58	bright	Went to paw of Gt. Bear. Leonid.		
4.00		Leonid meteor down south from Regulus.		
4.04		Direction of Sirius.		
4.05		Leonid towards handle of Gt. Dipper.		
4.08		Cumulus clouds drifting from north to south, obscured end star of Sickle.		
4.15		Clouds drifted away from Leo.		
4.15		Leonid direction of Castor.		
4.18		Leonid southeast.		
4.24	1°	Between Eta and Gamma to Regulus.		
4.25	5°	Came below Regulus, visible 3 seconds.	Brighter than Sirius	
4.27	10°	Southwest, visible 2 or 3 seconds.		
4.28	5°	Southwest, visible 1 second.	Sirius.	
4.34		Southeast from Regulus.		
4.34		" " "		
4.39	5°	Radiant toward Castor and Pollux; visible 3 seconds.	Very bright.	
4.43	long	Northeast toward Castor and Pollux, visible 3 seconds.		

Time.	Train.	Direction.	Mag.	Col.
4.49	20°	Iota Hydrae towards Regulus, visible 1s		
4.55		Southwest.		
5.05		Northeast.		
5.06	5°	Northwest (moonlight growing less).		
5.07		Northwest.		
5.07		Southeast.	Sirius.	
5.09		Southwest from Regulus, visible 2 seconds		
5.10		Southeast direction of Gt. Dipper.		
5.15		Due north, very swift, no train.		
5.15		" " " " " "		
5.22		Northwest direction of Bear's paw.		
5.26		Southwest.		
5.27	30°	West from Iota Hydrae to Corvus.	Procyon.	Gr.
5.28		" " " " " "		
5.30		Northeast. Light very dim, scarcely see to write.		
5.33		Southwest.		
5.34		"		
5.40		Light in the east, paled lustre of stars.		
5.44	30°	Southwest, visible a second or two.	Sirius.	
6.00	5°	Southwest. Dawn.		
		By Another Observer on 44th St.		
3.56		Leonid very long, left trail after disappearance.		
4.07		Leonid towards Big Dipper.		
4.12		Leonid long trail.		

Observers:—H. I. Woods and Mrs. Woods, N. Y. City, near Columbia Univ. Latitude, 40° 48′ 27″.3. Longitude, $4^h\ 55^m\ 54^s.5$. Condition of Sky, Clear.

Date.	Frequency of Meteors.			Individual Meteors.			
	Time of Beginning St. M. T.	Time of Ending.	No. of Meteors.	Time.	Class.	Magnitude.	Color.
1899.	h	h					
Nov. 15	14:15	16:45	36				
			Observer:—P. W. Jenkins.				
	h	h					
Nov. 14	13:50	15:10	3		Leonids.	3, 4, 3	White
15	12:00	14:00	Cloudy				

Observers: Miss E. Post and P. E. More, Bayport, L. I., Strandhome Obs. Latitude, 40° 43′ 52″. Longitude, 73° 3′ 2″. Condition of Sky, misty at first, then clear, then cloudy across meridian, then clear.

			Edith Post.				
Nov. 15	13:57	14:15	3				
"	14:30	15:00	3				
"	15:10	16:15	8				
"	16:35	17:35	8				
			Paul E. More.				
"	13:57	14:15	2				
"	14:30	15:00	–				
"	15:10	16:15	5				
"	16:35	17:35	10				

In the first watch Miss Post observed southeastern quarter of sky; I observed southwestern quarter. In the three following watches Miss Post observed east of meridian; I observed west of meridian. P. E. M.

Observers:—J. T. Crabbs, S. A. Mitchell, P. W. Jenkins, G. N. Bauer, West Point, N. Y.

Latitude, + 41° 23′ 22″.1. Longitude, $4^h\ 55^m\ 50^s.55$.

Date.	Frequency of Meteors. Time of Beginning.	Time of Ending.	No. of Meteors. Leonid	Other	Observer.	
	h m	h m				
Nov. 12	13 15 E. S. T.	14 0	5		M. &	Only one Leonid. Sky clear.
"	14 0 "	14 30	0		C.	
Nov. 13	13 10 E. S. T.	13 30	0		M.	
"	13 30 "	14 00	1			No Leonids. Sky clear.
"	14 00 "	14 30	0			
Nov. 14	Sky cloudy all night				M.	
Nov. 15	11 40	12 15	0			Cleared at $11^h\ 40^m$. Sky clear but quite hazy.
"	12 45	13 15	5	1		
"	13 15	13 45	1	0	M. B.	
"	13 45	14 15	1	1	& J.	
"	14 15	15 00	3	1		
Cloudy from 15^h to 16^h						
	16 0	16 30	2	2		
Clouded at $16^h\ 30^m$ and remained so till daylight.						
Nov 16	13 00	13 30	0	2	M.	Sky clear.
"	13 30	14 00	1?	1		
"	14 00	14 30	0	1		

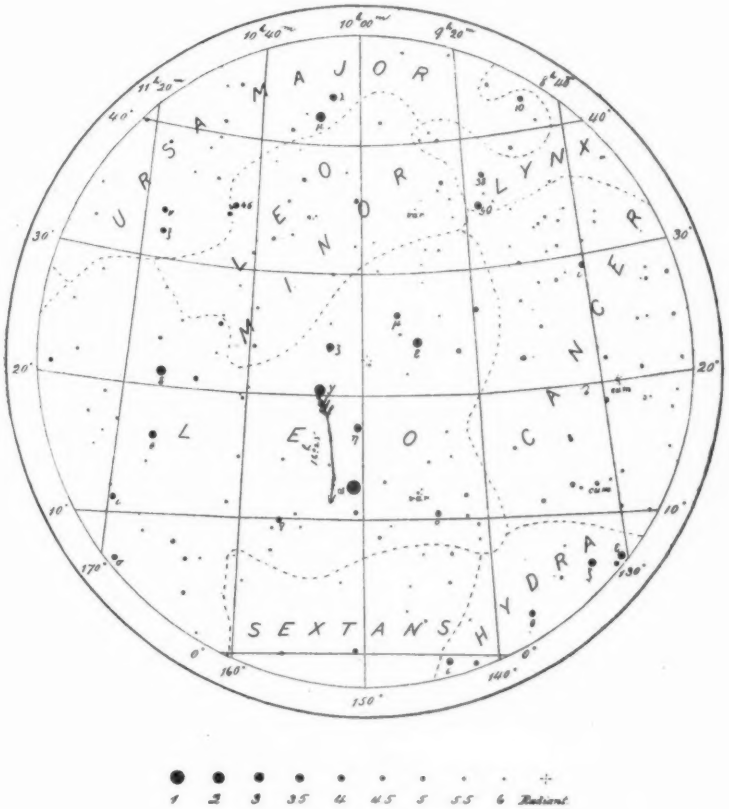
Observations at the Observatory of C. A. Post, Bayport, Nov. 14, 1898. The following record was taken at intervals of 15 minutes beginning at 11:45 and lasting until 4:45:

11:45 to 12	seven	(7)	
12 " 12:15	eight	(8)	
12:15 " 12:30	three	(3)	
12:30 " 12:45	twelve	(12)	
12:45 " 1	eleven	(11)	
1 " 1:15	ten	(10)	
1:15 " 1:30	six	(6)	
1:30 " 1:45	fifteen	(15)	
1:45 " 2	eleven	(11)	
2 " 2:15	fifteen	(15)	
2:15 to 2:30	seven	(7)	
2:30 " 2:45	five	(5)	
2:45	radiant obscured by clouds.		
3 to 3:15	ten	(10)	
3:15 " 3:30	eleven	(11)	
3:30 " 3:45	fifteen	(15)	
3:45 " 4	seventeen	(17)	
4 " 4:15	ten	(10)	
4:15 " 4:30	eighteen	(18)	
4:30 " 4:45	fifteen	(15)	

REMARKS. At 12:27 the most remarkable one was seen in the vicinity of the Pleiades extending south, train of the path visible for nearly three minutes.

At 1:34 one in almost exactly the same position was seen lasting nearly two minutes.

Orion and Taurus were the prevailing centers of the display.



BRIGHT LEONID METEOR OBSERVED AT NEW YORK CITY, NOV. 15, 1899, $16^h\ 25^m$.

Nearly two-thirds of all noted were between Procyon on the east and the Pleiades on the west and nearly all in the above vicinity were under the above named constellations and stars.

About five were noted in the supposed radiant, Leo.

No explosions were noted. Observations by M. H. Parker of Bayport.

Observers:—Miss Proctor and two friends at New York City, Nov. 14th, 1900.

No.	Condition of sky.	Position.	Standard Time. h	m	Class.	Mag.	Color
1	Clear	Radiant, long train	13	8	L.	2	blue
2		Gamma Leonis	13	13	L.	2	blue
3	Sky misty near Leo	Beta Ursæ Majoris	13	27	n.	2	y.
4		Mu Leo, long train	13	28	L.	3	b.
5		Orionid, short train	13	33	n.	4	y.
6		Gamma Leonis, long train	13	37	L.	2	b.
7		Gamma Leonis, short train	13	43	L.	2	b.
8	Clouds drifting N. E. covering Moon. Center of Sickle hazy.	Gamma Leonis	13	47	L.	2	
9		Epsilon Leonis long train	13	56	L.	3	b.
10		Radiant, short train	13	57	L.		
11	Clouds drifting N. W. toward Sickle.	Mu Leonis	14	00	L.	2	b.
12		Gamma Leonis	14	00	L.	2	
	Clouds drifting across Sickle and near Moon.	.....	14	11			
	Gamma, Eta, Alpha, only stars visible in Leo	.....	14	17			
	N.E. sky misty Sickle dim	.....	14	22			
13	Had to use lamp in making observations at 14h 22.	Orionid (fine)	14	22	n.	1	y.
	Misty, but clouds dispersing, all stars now visible in Sickle.		14	34			
	Moon and stars misty.		14	39			
	Haze clearing from region of Sickle.		14	46			
	Streaky clouds drift in direction of Leo. Sky clearer.		14	58			
14		Ursa Major, long train.	14	59	n.	2	
15		Gamma Leonis	15		L.	2	y.
16		Beta Leonis	15		L.	3	
17		Above Alpha Leonis.	15	4	"	2	b.
18	Sky clear.	Radiant, long train.	15	6	"	2	b.
19		Procyon.	15	16	n.	2	b.
20	Clouds drift across Sickle. Wind rising.	Mu Leonis, short train.	15	24	L.	3	b.
21		Radiant.	15	27	"	2	b.
22		Gamma Leonis.	15	36	"	3	b.
23		Gamma Leonis, long train.	15	52	"	2	b.
24		Gamma Leonis, short train.	15	53	"	3	b.
25		Near Regulus, long train, burst.	15	57	"	1	g.
26		Gamma Leonis.	16	5	"		g.
27	Clouds drifting toward Sickle. Now light enough to make observations without lamp.	Leonid, long train, burst.	16	23	"	2	b.
28		Radiant Leo.	16	45	"		b.
29	Clouds drifting toward Sickle. 16h 48.	Delta Leonis.	16	46	"	2	b.
30		Mu Leonis.	16	58	"	3	b.
31	Small clouds drifting around Sickle.	Mu Leonis, long train curved.	16	59	"		b.
32		Mu Leonis, short train.	17	5	"	3	b.
33		Gamma Leonis.	17	9	"	2	b.
34		Radiant, small train.	17	10	"	3	b.
35		Ursa Major.	17	11	n.		
36	Bands of clouds drifted across Moon and Sickle 17h 19m.	Radiant, short train.	17	12	L.		b.
37	Sky clear. 17h 23m.	Alpha Leonis.	17	20			
38		Gamma Leonis.	17	27	"	3	
39	Clouds drifting.	Mu Leonis (fine)	17	28	"	2	b.
40		Theta Leonis.	17	45	"	3	
41		Gamma Leonis, long train.	17	46	"	3	b.
42		Radiant.	17	48	"	4	
43		Beta Leonis.	17	48	"	3	
44		Radiant.	17	58	"	4	b.

Observer:—S. A. Mitchell, 58 Morning Side Ave., New York City.
Condition of Sky, Clear.

Date. 1900	Frequency of Meteors.			Individual Meteors.			
	Standard Time of Beginning	Stand'd Time of Ending	No. of Met'rs	Time.	Class.	Magnitude.	Color.
	h m	h m					
Nov. 12	11 15	11 30	1 n				
	11 45	12 00	1 n				
	12 00	12 15	0				
	12 15	12 30	0				
	12 30	12 45	0				
	12 45	13 0	1 n	12:51	Exploded	Bright as Sirius	White
Nov. 13	12 30	13 0	0				
	12 30 Floating clouds.						
	13 00	13 15	0				
	13 15	13 30	1 l				
	13 30	13 45	0				
	15 00	cloudy					
	17 05	17 20	1n 2l				
	17 20	17 35	1 l				
Nov. 14	13 10	13 30	2 n				
	13 30	13 45	0				
	13 45	14 0	2 l				
	13 50 Slight haze and cirrus clouds in the east.						
Nov. 15	11 45	12 00	1 n				
	12 00	12 15	1 n				
	12 15	12 30	2n 2l				
	12 30	12 45	1n 4l				
	12 45	13 0	1 n				
	13 45	14 00	3n 2l				
	14 0	14 15	5n 4l				
	14 15	14 30	1n 3l				
	14 30	14 45	2 1				
	14 45	15 0	0				
	15 0	15 15	1 l				
	15 15	15 30	0				
	15 30	15 45	1n 1l				
	15 45	16 0	0				

Total for four nights 22n, 25l. l stands for Leonid. n stands for other than Leonid.

C. A. Post and J. K. Rees, at Bayport, assisted by Misses E. Post and Edith Greenough.

Nov. 13, 1900—Two observers went out at various times about 1 hour apart between 10and 13. At times clouds interfered. Counted 15 meteors of which 8 appeared to be Leonids.

Nov. 14—Five observers were watchers from about 9:30 to 15:30. Counted 87 meteors, most appeared to be Leonids. There were several Geminids and Orionids. Several were very bright. One exploded beautifully a little west of the zenith at 11:55.

Nov. 15—Post observed, going out a few times before 12, only a few meteors were seen. J. K. Rees was in N. Y. City and looked out at 9:00, 10:00, 11:30 13:00, 15:00, 16:00 and saw no meteors.

Dr. Mitchell was ready to photograph in New York City. He saw only a few meteors, about 10 an hour, while he watched.

DETERMINATIONS OF THE SUN'S DISTANCE FROM OBSERVATIONS OF EROS.*

W. W. CAMPBELL.

The tendency of the times toward thorough organization and co-operation in large enterprises is well illustrated in modern astronomy. Thirty years ago, a dozen leading observatories, by mutual agreement, divided the northern sky into zones in such a way that their meridian-circle observations would combine to form the excellent *Astronomische Gesellschaft* star-catalogue; and this great work is now nearing completion. The work of charting the sky by means of photography was similarly organized by the Astrographic Conference in Paris, some ten years ago.

About fifty of the principal observatories of the world are now co-operating in a great programme of observation for improving our knowledge of the distance between the Earth and Sun. Fully half the resources of the Lick Observatory have been devoted to this work for two months past, and the observations will continue one or two months longer.

The determination of the value of this astronomical unit of distance is one of the most famous problems in the science, and a great variety of methods has been used. Perhaps the best determination is that made by Sir David Gill of the Cape of Good Hope, from heliometer observations of the nearer asteroids. The four hundred small planets (asteroids) discovered up to 1898 all move in orbits situated entirely outside the orbit of Mars. The observations of Victoria, Iris, and Sappho, which approach nearer to the Earth than any of the other members of the asteroid group, led to the result that the average distance from the Earth to the Sun is about 92,900,000 miles. The unavoidable errors to which all such observations are subject leave an uncertainty of some 150,000 miles in this value: it may be too large or too small by this amount.

The accuracy of results obtained in this manner depends upon the distance of the observed body from the Earth, and upon its definiteness as a point of observation. Mars possesses the advantage of being nearer the Earth than the asteroids, but this advantage is greatly outweighed by the fact that an asteroid-point can be observed much more accurately than a large planet-

* Reprinted from *Publications of the Astronomical Society of the Pacific*, Vol. XII, 1900.

disk. Gill's splendid work left much to be desired, but there was no prospect that his value of the unit could be improved with instruments now available.

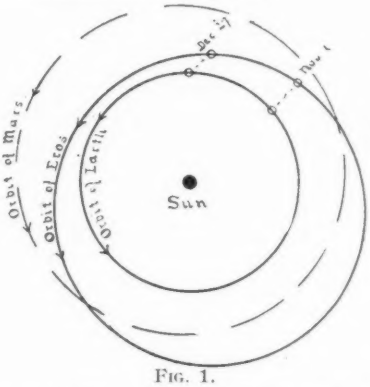


FIG. 1.

An asteroid discovered by Dr. Witt in Berlin, in 1898, to which he gave the name Eros, is very remarkable in that its orbit lies partly within and partly without the orbit of Mars. It approaches the Earth more closely than any other member of our system, except the Moon. The forms and relative positions of the orbits of the Earth, Eros and Mars are shown approximately by the accompanying diagram (Fig. 1). The orbits of Mars and Eros appear to intersect; but this is merely apparent, from the projection of the two on the plane of the paper. The plane of the orbit of Eros makes an angle of about eleven degrees with the plane of the orbit of Mars (and the Earth), and the two orbits are situated like two adjacent links of a chain without approaching each other very closely.

As soon as the orbit of this wonderfully-located asteroid was computed and published, astronomers realized its possibilities for improving our knowledge of the Sun's distance. As stated above, an asteroid's value for this purpose depends upon its closeness to the Earth. The distance of Eros at this opposition will have a minimum value of 27,000,000 miles. Unfortunately, the more favorable opposition of 1896, when the distance diminished to 15,000,000 miles, was not available, as the planet remained undiscovered; and an equally good opposition will not occur again for a quarter of a century.

In outline, this method of measuring the Sun's distance is exceedingly simple; but in detail it is exceedingly complex and technical. The nature of the problem may be explained from Fig. 2.

If the Earth is at E and the asteroid at A, an observer on the Earth's surface at P will see the asteroid projected on the sky at P', whereas an observer at L will see it at L'. If the distance PL is known, as it is, and the angle PAL is obtained from the observations, the data for solving the triangle PLA are at hand, and the distance EA may be obtained by simple computation. As a

second step in the solution, the orbit of Eros will be determined very accurately, basing the determination upon Newton's law of gravitation. It will then be a simple matter to compute the ratio of the Earth's distances from the Sun (*ES*) and the asteroid (*EA*). The distance *EA* having already been determined in miles, the desired distance *ES* will follow.

If two observatories on opposite sides of the Earth secure observations simultaneously, say at *P* (Pulkowa, in Russia) and at

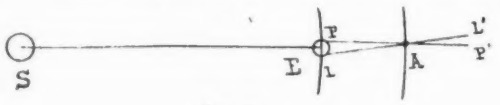


FIG. 2.

L (Mt. Hamilton), the desired data are theoretically complete; but practically they are insufficient. There are unavoidable errors in the measurement of the very small angle *PAL*, and in the assumed positions of the two observatories, which will be materially reduced by having observations made at a large number of stations. The direct distance between the Pulkowa and Lick Observatories is about 5,000 miles. This is a base-line from which to measure a distance of 27,000,000 miles, and thence the three and one-half fold greater distance to the Sun. The form and the dimensions of the Earth thus enter directly into the problem. An error of a quarter of a mile in the assumed length of the base-line leads to a large error in the final resnlt.

Instead of simultaneous observations made in the morning in Russia and in the evening in America, the angle *PAL* can be determined by evening and morning measures secured at one station.

The July conference of astronomers at the Paris Exposition afforded an opportunity for a hurried formation of co-operative plans to secure the observations needed. It may be said that every one of the contributing observatories is devoting to this problem all of its resources which in any way promise to improve the results. The measures are most advantageously made in November and December; and perhaps a hundred observers are giving their time to this work. The reductions will require one or two years' labor, and the value of the Sun's distance, resulting from a combination of all the work of all the observatories will probably not be available for two or three years.

The Lick Observatory is contributing as follows:

Astronomer R. H. Tucker, assisted by Mr. Crawford, is securing two meridian circle observations of each of 700 stars, to

determine their positions with the utmost accuracy. These positions, furnished by perhaps a dozen or more observers, will form the triangulation system, or groundwork, upon which the whole structure of the determination will be based.

Astronomer W. J. Hussey and Assistant Astronomer R. G. Aitken, with the assistance of Mr. Wright and Dr. Reese, are using the great telescope five or six nights per week, weather permitting, to measure the evening and morning positions of Eros with reference to the fixed stars in the asteroid's vicinity. The positions of these reference-stars will be secured by means of photographs of the regions taken with eight or ten telescopes, mostly in Europe.

Assistant Astronomer C. D. Perrine, assisted by Mr. Palmer, is employing the Crossley reflector every clear night to obtain photographs of Eros and its surrounding stars, to furnish the planet's accurate position in the evening, in the morning, and on the meridian. The measurement of these plates will be a heavy task. Fortunately, Professor Rees, director of the Columbia University Observatory, has volunteered to measure them. Columbia University is the only institution in this country which has had experience in measuring such plates, though many foreign observatories have long been doing similar work.

The planet Eros is now of about the 9.3 magnitude. It is easily visible in a three-inch telescope.

LICK OBSERVATORY,
November 24, 1900.

SCIENTIFIC PROGRESS DURING THE NINETEENTH CENTURY.*

"Not in vain the distance beacons. Forward, forward, let us range;
Let the great world spin for ever down the ringing grooves of change."

The year upon which we have just entered announces the dawn of a new century. Could one but draw the word-pictures of social England as it was in the year 1801, and as it is today, after the lapse of one hundred years—years teeming with the fruits of genius in every walk of life—the contrast between the two periods would form a convincing proof of the intellectual development and the amplification of the resources of the people

* Extract from *Knowledge Diary*, 1901.

—advantages won by a bloodless victory of mind over matter. Yet there is in reality no gulf between the past and the present. The men whose doings have laid the foundation of our commercial prosperity belong to a past age, and we who carry on the appointed work of improvement and civilization are their progeny and belong emphatically to past times. Theirs was the understanding at once penetrating and vigilant, but more distinguished, perhaps, for the caution and sureness of its march than for the brilliancy or rapidity of its movements. The mind of man in its progress towards its higher destiny is confronted, in the main, with the physical Earth as a problem which, within the limits of a life, it must struggle to solve. The intellectual spirit is capable of embracing all finite things. Science alone can interpret their mysterious whispers. It requires an effort of the imagination to the great bulk people now living to realize what the condition of life must have been at the beginning of the 19th century. Divested of the luxuries which science has heaped upon us since that auspicious epoch, we should lapse into a state of civilization which would more nearly resemble that of ancient Greece and Rome than that to which we have attained at the present time.

One of the factors too important to ignore in the grand sum of scientific progress during the century is the Royal Institution, which was founded in the year 1800. "Its aim and objects were to diffuse the knowledge and facilitate the general introduction of useful mechanical inventions and improvements, and to teach by philosophical lectures and experiments the application of science to the useful purposes of life." Count Rumford, to his lasting credit be it said, was the chief promoter of this temple of science, which can boast of having given in its early days employment to Young, Davy, Brande and Faraday. This institution may, with some regard for truth, be looked upon as the nursery in which the plants that have yielded so much fruit in their maturer years were tended in their infancy. By whom? By men who were our progenitors in science—patient, indomitable, calmly and wisely bold, modestly self-reliant, ever watching, ever toiling, ever adding to the store of knowledge that was to benefit not them alone but the great human race; each guided by his own perceptions of what is great in humanity and fitting in a nation —men whose instinct it was to work for the world and fight against misery.

The progress of astronomy has been, on one side, a development; on the other, a metamorphosis. While the traditional

methods have been improved, and traditional aims pursued with ever-increasing diligence, novel methods have come into use—novel methods of such transforming power that the science has, in a measure changed its aspect and attitude. One hundred years ago it stood apart, in close alliance with mathematics. Now it appeals for aid to chemistry and optics, to electrical, thermal, and molecular investigations. Every new fact ascertained in a laboratory has a bearing upon some cosmical problem; every well-grounded theory of matter and force finds its application in the heavens. These intricate relations possess a significance as yet imperfectly apprehended; they may lead to generalizations of a higher order than any so far attained. Their establishment is a higher than any so far attained. Their establishment is the cardinal event in recent astronomical history.

Astrophysics took its rise in 1851 from Schwabe's discovery of the sunspot period; for it was quickly perceived that the magnitism of the Earth, including auroral displays, obeyed an identical law of change. Thus terrestrial phenomena acquired an universal import, and became affiliated to cosmical vicissitudes. The chemical interpretation given by Kirchoff to the hieroglyphics of the solar spectrum drew the connecting bonds closer. He announced to the Berlin Academy of Sciences, December 15th, 1859, the presence in the Sun of sodium, iron, magnesium, calcium and some other familiar metals. The evidence warranting these identifications was the agreement of certain "Fraunhofer lines" with the individual rays given out by the glowing vapors of the substances in question, coupled with the fruitful root-principle of the correlation of emission and absorption. The position of each isolated ray in the dispersed light of a heavenly body was thus shown to be indicative of its constitution, and the *impossible*—as Comte had declared acquaintance with such facts to be—was achieved.

The science of astrochemistry developed rapidly. About thirty-six elements, including hydrogen and carbon, have been recognized as common to Sun and Earth, and those missing need not be supposed absent. Three among them—antimony, bismuth, and mercury, all heavy metals—early declared themselves in the red stars, Aldebaran and Betelgeux; and some fine lines belonging to oxygen—a long-sought and evasive substance—have apparently just been picked out by Runge and Paschen from Mr. Higg's solar spectral photographs. Undetermined lines, however, still abound in celestial spectra, to an extent, it might almost have been thought a few years ago, seriously compromising the

prospects of advancing knowledge. But Professor Ramsay s enfranchisement from its millennial prison in a Norwegian mineral of the solar gas helium, has effectually dissipated these misgivings. Its highly complex spectrum figures bright in the solar chromosphere, in nebulæ, and temporary stars; dark, in a restricted class of white orbs, a complete battalion of which are arrayed in the constellation Orion.

The stars were, in 1863, brought by Dr. Huggins and Professor W. A. Miller within the scope of Kirchoff's conclusions. Their chemistry proved to be generically the same with that of the Sun, although with decided specific differences. They were divided by Father Secchi into four spectral orders; and his classification has been in the main adhered to by Professor Vogel, who added the "rationalising" idea of decline with increasing age, from the culminating splendor of the Syrian type, through a solar stage, to the waning fires of red stars showing banded spectra. His scheme of decay was enlarged into a scheme of development by Mr. Lockyer, who begins at the beginning with the nebulæ; but it is unlikely that time is the sole factor in producing the observed varieties of sidereal species.

Dr. Huggins began his investigations of nebular spectra on August 1st, 1864. The first he looked at consisted of one bright and two fainter green rays, the most refrangible being the "F" of hydrogen. He had selected for examination the "planetary" in Draco, and all nebulæ of that kind, as well as those of irregular shape like the great formation in Orion, are of gaseous constitution. But he soon found that most nebulæ, and notably the vast ellipse in Andromeda, give a continuous spectrum such as might be derived from distant star clusters. The manner of their distribution separates them emphatically, nevertheless, both from gaseous objects and from true clusters, the latter two classes belonging characteristically to the zone of the Milky Way, while ordinary nebulæ gather towards its poles.

The rapid progress of astronomy in our time along the old no less than the new lines of research, has been largely due to its adoption of photography as an ally. The services which this wonderful art has proved capable of rendering have distanced hope. The staying power of the chemical plate, its faculty of waiting upon time and integrating infinitesimal impressions, has led to the partial abdication in its favor of the human eye. It has the further prerogatives of sensibility to *invisible* light, of swiftness in procedure, and of affording permanent and absolutely truthful records. There is no imagination behind it.

Celestial photography is predominately employed in four de-departments of inquiry: in direct portraiture, in the discovery of new objects, in star charting, and in the delineation of spectra and spectral forms. Warren de la Rue was the earliest promoter in this country of solar and lunar photography. With his "photoheliograph" the daily registration of sunspots was begun at Kew in 1858; and the same instrument served, during the Spanish eclipse of July 18th, 1860, to depict the "red prominences," the mere display of which, as progressively covered on one side and uncovered on the other by the moving globe of the Moon, sufficed to demonstrate their solar dependence. A daguerreotype of the corona of 1851 is still extant; and coronal photography has grown to be an art in itself, practiced, weather permitting, with added success, each time that the mysterious solar nimbus starts into view from behind the interposing Moon. It imprinted itself with particular effectiveness on plates exposed by Sir George Baden Powell at Novaya Zemlya, August 9th, 1896. The instructive details of its intimate structure can be studied only by means of such authentic records. A photograph of the "reversing layer," fortunately secured on the same occasion by Mr. Shackleton, locates the chief seat of the Fraunhofer absorption in a shallow stratum near the photosphere. The phenomenon had been spectroscopically viewed as a flash of bright rays by Professor Young in 1870.

Comets and nebulæ are slow in self-portraiture; which was, indeed, rendered practicable only by the invention of dry-plates with their attendant facility for long exposures. Hence, the first comet successfully recorded was Tebbutt's in June, 1881; while some photographs of the great September comet of 1882, obtained by Mr. Allis at the Cape Observatory under Dr. Gill's supervision, started and exemplified two broad streams of laborious inquiry. Taken with a common portrait-lens, their perfection showed the advantages of the wide field of view and strong concentration of light afforded by that type of instrument; and the richness of their star-sprinkled backgrounds irresistably suggested the use of the camera for the preparation of stellar charts and catalogues. No brilliant comet has appeared since 1882; but between 1892 and 1894 several minor apparitions were photographed by Professor Barnard night after night, with the "Willard lens" of the Lick Observatory. The multiple nature and fibrous composition of their tails, imperceptible telescopically, came out strikingly upon his negatives, which testify besides to irregular effluxes of nebulous matter from the heads.

Dr. Henry Draper obtained a promising photograph of the Orion nebula, September 30th, 1880; and Dr. Common's classic pictures of the same object, by which the future of nebular self-delineation was assured, followed in 1883. Dr. Roberts next entered a field in which he has won signal success. A plate exposed for three hours, with his twenty inch reflector, October 8, 1888, disclosed the Andromeda nebula in its true annular or spiral shape—furrowed, as it were, by the action of some mighty unknown force.

Professor Barnard undertook in 1889 the task of photographing the milky way. The star-clouds and star-sprays constituting it can neither be seen nor depicted with an ordinary telescope. They must be taken in the mass, not bit by bit. The Willard lens however, proved equal to the occasion, and a series of astonishing galactic views were produced, in which lucid piles and drifts of saw-dust are singularly interrupted by black chasms, cracks and vacuities.

The eye sees at once, or not at all; the camera sees by degrees; hence its effectiveness as an engine of discovery. It brings into cognizance the contents of depths of space unsounded by the telescope, as well as objects hidden by their intrinsic faintness, or by the quality of their radiations.

The first photographic detection of a comet fell to the share of Professor Barnard, October 12th, 1892. Had it not been for the intervention of the Willard lens, the object might have altogether escaped notice. It proved to have a period of six years, and seemed to have exhausted its vitality. In asteroidal discovery by the same versatile method, Dr. Max Wolf led the way.

The only photographic star-catalogue as yet existing is Dr. Gill's "Cape Durchmusterung," the first volume of which, containing one hundred and fifty-two thousand and five hundred entries, has been issued from the press. In all about three hundred and fifty thousand stars, measured from the Cape plates by Professor Kapteyn, are enrolled in this comprehensive survey.

With the apparatus in use at Harvard College, star-spectra can be photographed by the score together; and as a result of these expeditious proceedings, the "Draper Catalogue" of ten thousand three hundred and fifty-one stars, referred to fifteen spectral subdivisions, appeared in 1890. At Potsdam, when the same kind of work was executed with a slit spectroscope instead of with an objective prism, a few bright stars were made the subjects of a stricter examination.

Christian Doppler, of Prague, announced in 1842 the principle of an alteration in the refrangibility of light emanating from a source retreating or advancing relatively to an observer. It is, indeed, tolerably obvious that the ethereal waves must be virtually lengthened in the first case, shortened in the second; and the rate, no less than the direction of radial movement, can be ascertained, as Fizeau showed in 1848, by measuring the displacements of lines, bright or dark, in the spectra of the moving bodies. Twenty years, however, elapsed before any attempt was made to realize the indicated method. It was reserved for Dr. Huggins, in 1868, to apply it practically to stars and nebulæ.

Dr. Vogel, director of the Potsdam Observatory, ably seconded by Dr. Scheiner, initiated, in 1888, the spectrographic measurement of radial movements, and the details of his model investigation were published in 1892.

The discovery of "spectroscopic binaries" is one of the most striking fruits of the line-of-sight method. Miss Maury's examination of the Harvard photographs showed, in 1889, that the lines in the spectrum of ζ Ursæ Majoris separate and close up again once in fifty-two days, obviously as a consequence of the orbital revolution in twice that time of a pair of suns. Soon afterwards, β Aurigæ was similarly decomposed, the spectral duplications taking place, however, on alternate days; and two unequal couples, with still shorter periods, have since been discovered at Harvard. Systems equally rapid are formed by the union of bright with dark components. They are recognized by the occurrence of periodical opposite displacements in the single spectrum of the obscurely attended star. Spica Virginis is of this kind. Its peculiar character was detected photographically at Potsdam. A number of variables belong to the same type, notably Algol, and other eclipsing stars. Less intelligibly, δ Cephei and its congeners, in which the law of light change appears to exclude eclipses, range themselves unmistakably in the category. Some of these extraordinary couples circulate in a few hours, most likely with enormous velocities.

The combination of lucid with obscure, or partially obscure, masses appears to be a regular part of the cosmical scheme. The presence of dark stars in ordinary stellar systems is not unfrequently betrayed by their gravitational effects upon the movements of their bright fellows. Examples are met with in ζ Cancri and 70 Ophiuchi. The dusky attendants, too, of Syrius and Procyon were predicted by Bessel as necessary to explain the undulating proper motions of the Dog Stars long before they were

actually seen; the former, by Clark in 1862—the latter, probably, by Schaeberle in 1896. The "astronomy of the invisible," however, achieved its highest triumph in the discovery of Neptune. The influence of an exterior planet had been more or less definitely *felt* through the perturbations of Uranus; but only such mathematical giants as Adams and Deverrier were competent to assign its place at a given epoch. Adams had the priority, but his indications were neglected until reinforced by those of his French competitor; and while a leisurely search was slowly progressing at Cambridge, the new planet was picked up, almost at the first glance, by Galle at Berlin, September 23rd, 1846. The possession of a fine star map gave him, it should be added, a decisive advantage over Challis.

The earliest information regarding the spectrum of the solar prominences was secured during the Indian eclipse of August 18, 1868. It proved to consist of a few bright lines of hydrogen and helium; and its discontinuous nature enabled Janssen and Lockyer to realize the spectroscopic method of daylight observation at the edge af the Sun, by means of which the chromosphere and its prodigious outlaying flames have since been unintermittently studied. The forms spectroscopically viewed have of late been successfully photographed. The employment for this purpose, by Hale and Deslandres in 1891, of an apparatus with a double slit, marked the opening of a chapter in solar physics. A single quality of light is thus effectively isolated; and both at Chicago and Paris the shadowed "K line" of calcium was chosen as the actinic agent. The same ray is emitted by faculæ, which, with its aid, can be photographed all over the Sun's surface.

Since 1837, seven secondary bodies have been added to the planetary system. On October 10th, 1846, Mr. Lassell's famous two-foot speculum showed him Neptune's solitary moon, and, five years later, the two inner Uranian satellites. He espied, moreover, September 19th, 1848, simultaneously with W. C. Bond on the opposite shore of the Atlantic, Hyperion, the seventh in order of distance, and eighth in order of discovery, of Saturn's numerous family. The disclosure of Professor Hall, August 16th, 1877, of Deimos and Phobos, the dwarf moons of Mars, was the most eminent performance of the Washington twenty-six-inch refractor, which for some years held the telescopic primacy of the world; and it was with a later champion instrument, the Lick thirty-six-inch, that Professor Barnard described, September 19th, 1892, the small body called, without rhyme or reason, the "fifth satel-

lite of Jupiter." Among the eight principal planets, Mercury and Venus alone remain unattended; and this circumstance is, more than probably, connected with their peculiar mode of rotation. Each—as Schiaparelli announced in 1889-90—turns on its axis in the same time that it revolves round the Sun, keeping, like our Moon, the same face always towards the central body. This agreement was, doubtless, brought about by the grinding down of axial movement through solar tidal friction, the epochs of instability leading to the birth of satellites being, as a secondary effect, forestalled. The importance of tidal friction in cosmogony came to be recognized through Professor Darwin's brilliant research into the origin of the Moon. It was presented to the Royal Society in 1879. The predominance of the same influence over the development of stellar systems was ably shown by Dr. See, of Chicago, in 1892.

SPECTROSCOPIC NOTES.

The first volume of Professor Kayser's elaborate Handbook of Spectroscopy (*Handbuch der Spectroscopie*, von H. Kayser, Leipzig, 1900) has apppeared. The remaining three of the four volumes are promised at short intervals, with, later, a fifth devoted to astronomical spectroscopy. In his attempt to make the work accurate and exhaustive Professor Kayser has found it necessary to examine the spectroscopic articles in a great variety of journals, physical, chemical and astronomical, and to consult a large number of separate spectroscopic publications. While in style the work is narrative, it is rather encyclopedic in content.

In the present volume references to astronomical spectroscopy are fewer than might be expected in a work on general spectroscopy; which is probably accounted for by the prospective addition of a volume given to the astronomical portion of the subject. In chapter 1, on the history of spectroscopy, Fraunhofer's work is of course described, but, while his pioneer work on star spectra is mentioned, it might be held to deserve as much space as Lamont's subsequent observations on the same subject. The early observations on star, nebula, and comet spectra are described. The first spectroscopic observations of the solar prominences receive two pages, but the study of the chromosphere lines is not mentioned. In chapter 2, on the radiation of incandescent gases Wilsing's experiments producing artificially the spectra of new stars are described, reference being given, however, to only one of the publications in which it appears. In chapter 5, on spectroscopic apparatus, the Purkinje phenomenon as affecting the determination of the variability of the lines in the spectrum of the Nebula of Orion is discussed under the head of the sensitiveness of the eye, and the construction of spectroscopes intended for visual observations of the spectra of meteors is described.

So complete a treatise on spectroscopy will be useful permanently; and conspicuously useful for that very short interval, the present of spectroscopy.

In the *Astrophysical Journal* for November Mr. Wright describes the auxiliary apparatus of the Mills spectrograph of the Lick Observatory for photographing the comparison spectra. Two electrodes are placed beyond the ends of the slit

and slightly before the plane of the slit plate, and the light from them is reflected into the spectrograph by two reflecting prisms before the slit, one on each side of the star image. Lenses are placed between the electrodes and reflecting prisms to secure that the light from the electrodes shall completely fill the collimator lens of the spectrograph. The exposures for the comparison spectra are made at intervals during the exposure for the star spectrum, and without interrupting it.

Sir Norman Lockyer and Dr. W. J. S. Lockyer (*Nature*, Nov. 29, Dec. 6) on examination of records find a connection between the rainfall of India, and of other countries as well, and the state of the Sun. They point out that in spots seen at times of sunspot maximum the spectrum lines widened are unknown lines, indicating probably an excess of solar temperature; while in spots seen at times of scarcity of sunspots the widened lines are known lines, indicating probably a deficiency of solar temperature. At times of high and of low solar temperature they find records of rain in India, but at times of mean solar temperature, as indicated by equal widening of the known and the unknown lines in the spectrum they find records of failure of rainfall, and consequently of famine. In particular at the time of the recent severe famine they find an abnormal duration of the solar conditions unfavorable to rainfall.

In the *Astrophysical Journal* for December Professor Frost gives a long account of his observations at the total eclipse of May 28. With a train of three large prisms were secured photographs of the spectra of the solar cusps ten seconds before and after totality, showing conspicuously the bright chromosphere lines, and most of the dark lines of the spectrum ending in bright tips; photographs of the flash spectrum at second and third contacts, permitting measures of a large number of lines; and a photograph of the violet of the corona spectrum, beginning about ten seconds after first flash and continuing thirty seconds, showing two hydrogen rings, a corona ring at λ 4230, a strontium arc at λ 4215, and several very faint rings. Successful photographs of the flash spectrum secured at both contacts were obtained by a small concave grating. For visual observation of the flash in order to determine the proper time for making the exposures of the other spectroscopes a plane objective grating was used; in which the flash was much less striking than was expected. An attempt to secure the red of the flash spectrum with a large plane grating was unsuccessful, except that a few faint bright and dark lines were obtained in the spectrum of the solar cusp after totality.

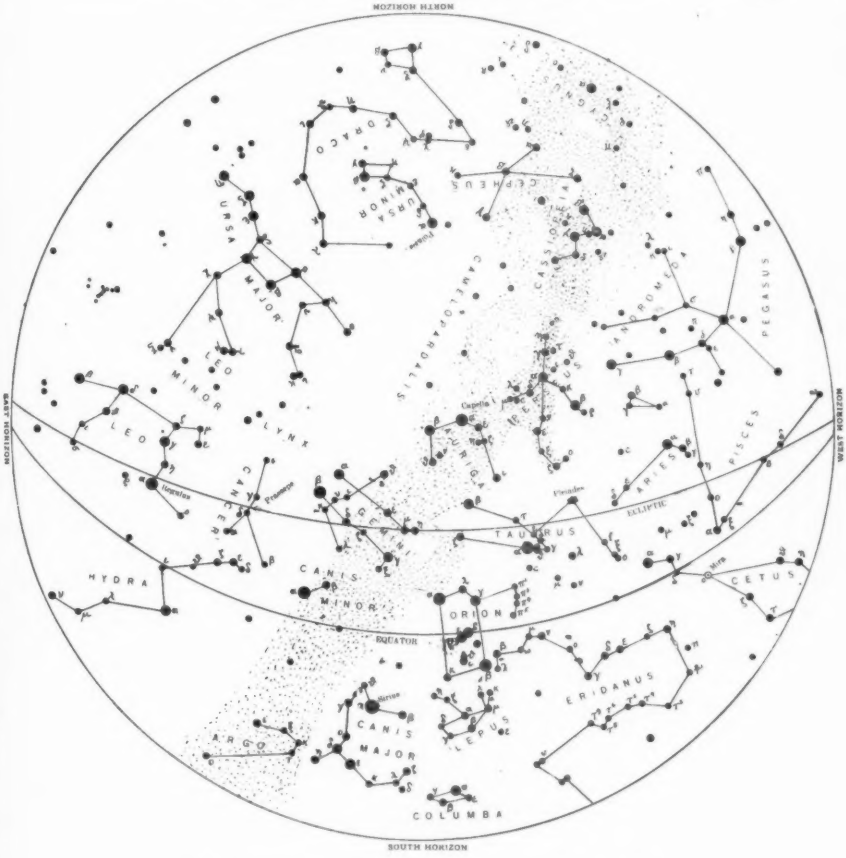
Professor Mohln and Mr. Daniel also used a concave grating to obtain photographs of the spectrum of the reversing layer at second and third contacts, and of the corona spectrum.

The Director of the Harvard Observatory in his annual report emphasizes the need of additions to the computing force of the Observatory to complete the preparation of a large quantity of observations for publication. Among these are, Spectra of Bright Southern Stars, a half volume of the annals, now partly in type; Peculiar Stellar Spectra, one volume, including novæ, gaseous nebulæ, variable stars, fourth and fifth type stars; Second Draper Catalogue, two volumes, giving spectra of 30,000 stars of eighth magnitude and brighter from the north to the south pole. The work of the Draper memorial has been actively prosecuted with the 11-inch and 8-inch telescopes. Of the variable stars discovered, ten, about half of all, were found by detecting bright hydrogen lines in their spectra. The $H\beta$ line of hydrogen was found bright in the star A.G.C. 8991 and variable in η Centauri and κ^2 Apodis.

PLANET NOTES FOR FEBRUARY.

H. C. WILSON.

Mercury is evening star during this month, being at greatest eastern elongation, 18° 7′ from the Sun, Feb. 19. As Mercury will then be also about 8° north of the Sun it will be visible for over an hour and a half after Sun set. This will therefore be a very favorable month for naked eye views of Mercury. The course



THE CONSTELLATIONS AT 9 P. M., FEBRUARY 1, 1901.

of the planet, as will be seen by reference to the chart in our January number, lies through the constellation Aquarius, where there are no bright stars to be confused with it.

Venus is morning star seen now only an hour and a half before sunrise.

Mars comes to opposition Feb. 21, at midnight central standard time, and is therefore in good position for observation. The planet this year in the part of its orbit most remote from the Sun, aphelion occurring Feb. 24. Its distance from the Earth is therefore about as great as it ever can be at opposition, amounting to 63,000,000 miles at the point of nearest approach on Feb. 23. The apparent diameter of the planet is now 14″ and will increase to nearly 15″ at opposition. During this month the satellites of Mars should be visible in the great telescopes. We give therefore a table of the times when the two satellites Phobos and Deimos will be at greatest distance east and west from the planet, omitting for Phobos the series of elongations which occur during daylight in the United States.

Jupiter, *Saturn* and *Uranus* are morning stars but not yet in convenient position for observation.

Neptune is near the meridian in the early evening and in very convenient position for observation by those having telescopes of sufficient power to recognize its disc. Neptune's position Feb. 15 will be in R. A. $5^h\ 45^m\ 9^s$ and Decl $+\ 22^\circ\ 10'\ 59''$. The motion is so slow that this position will serve for finding the planet during the month.

The Moon.

	Phases.	Rises. (Central Standard Time at Northfield; Local Time 13m less).	Sets.
		h m	h m
Feb. 3	Full Moon	5 54 P. M.	7 35 A. M.
11	Last Quarter	1 02 A. M.	10 45 "
18	New Moon	6 30 "	5 42 P. M.
25	First Quarter	10 41 "	2 13 A. M.

Occultations Visible at Washington.

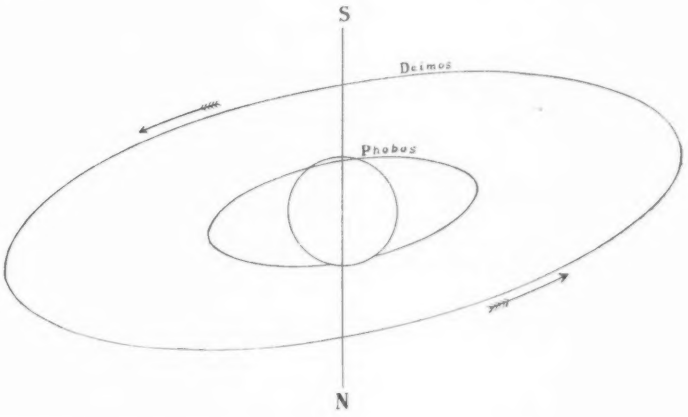
Date. 1901.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	IMMERSION. Angle from N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle from N pt. °	Duration. h m
Feb.	1	1 Cancri	5.9	14 37	108	15 43	294	1 06
	2	A′ Cancri	5.6	11 10	180	11 45	229	0 35
	2	60 Cancri	5.7	18 24	87	19 12	312	0 48
	8	*i* Virginis	5.5	12 16	127	13 30	288	1 14
	13	58 Ophiuchi	5.0	14 20	87	15 22	285	1 02
	15	B.A.C. 6710	6.0	15 30	95	16 27	254	0 57
	22	100 Piscium	6.8	3 54	354	4 20	316	0 26
	26	B.A.C. 1867	7.2	14 46	61	15 25	315	0 39
	27	22 Geminorum	7.2	6 49	146	7 48	230	0 59
	28	W. B. 7^h 685	6.2	8 17	157	9 13	236	0 56

Central Standard Times of the Eastern and Western Elongations of the Satellites of Mars.

		PHOBOS. East. A. M. h	PHOBOS. East. P. M. h	PHOBOS. West. A. M. h	PHOBOS. West. P. M. h	DEIMOS. East. A. M. h	DEIMOS. East. P. M. h	DEIMOS. West. A. M. h	DEIMOS. West. P. M. h
Feb.	1	...	7.7	...	11.6	...	7.3	4.2	...
	2	3.4	6.7	7.3	10.6	...	...	10.5	...
	3	2.4	5.7	6.2	9.5	1.6	...	...	4.8
	4	1.8	4.6	5.2	8.5	7.9	...	...	11.1
	5	12.3	11.3	4.1	7.4	...	2.2	...	...

	PHOBOS.				DEIMOS.			
	East.		West.		East.		West.	
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
	h	h	h	h	h	h	h	h
Feb. 6	6.9	10.2	3.1	6.4	...	8.5	5.3	...
7	5.8	9.1	2.0	5.3	...	...	11.6	...
8	4.8	8.1	1.0	11.9	2.7	...	...	5.9
9	3.7	7.0	7.6	10.9	9.0	...	...	...
10	2.7	6.0	6.5	9.8	...	3.3	12.1	...
11	1.6	4.9	5.5	8.8	...	9.5	6.4	...
12	12.6	11.6	4.4	7.7	...	...	...	12.7
13	7.2	10.6	3.4	6.7	3.8	...	...	6.9
14	6.2	9.5	2.3	5.6	10.1	...	...	...
15	5.2	8.5	1.3	4.6	...	4.3	1.2	...
16	4.1	7.4	12.2	11.2	...	10.6	7.5	...
17	3.1	6.4	6.9	10.7	...	...	...	1.7
18	2.0	5.3	5.8	9.1	4.8	...	...	8.0
19	1.0	11.9	4.8	8.1	11.0	...	...	...
20	7.5	10.9	3.7	7.0	...	5.3	2.2	...
21	6.5	9.8	2.7	6.0	...	11.6	8.4	...
22	5.4	8.7	1.6	4.9	...	...	...	2.7
23	4.4	7.7	12.6	11.6	5.8	...	...	9.0
24	3.3	6.6	7.2	10.5	...	12,1	...	...
25	2.3	5.6	6.2	9.5	...	6.4	3.2	...
26	1.2	4.5	5.1	8.4	...	...	9.5	...
27	12.2	11.2	4.1	7.4	12.6	...	...	3.7
28	6.7	10.1	3.0	6.3	6.9	...	...	9.9

Periodic time of Phobos $7^h\ 39^m\ 13^s.85$. Periodic time of Deimos $30^h\ 17^m\ 54^s.86$.



APPARENT ORBITS OF THE SATELLITES OF MARS DURING THE OPPOSITION OF 1901, AS SEEN IN AN INVERTING TELESCOPE.

The circle represents the disc of the planet and is on the same scale as the orbits.

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time).

1901.

U CEPHEI.

	d	h
Feb.	5	5
	10	5
	15	5
	20	4
	25	4
Mar.	2	4
	7	3
	12	3
	17	3
	22	2
	27	2

ALGOL.

	d	h
Feb.	4	0
	9	17
	15	11
	21	5
	26	23
Mar.	4	16
	10	10
	16	4
	21	21
	27	15

R. CANIS MAJ.

	d	h
Feb.	1	4
	4	14
	7	23
	11	9
	14	19
	18	5
	21	14
	25	0
	28	10
Mar.	3	20
	7	6
	10	15
	14	1
	17	11
	20	21
	24	7
	27	16
	31	2

W DELPHINI.

	d	h
Feb.	13	11
	27	21
Mar.	14	7
	28	17

λ TAURI.

	d	h
Feb.	3	6
	11	4
	19	1
	26	23
Mar.	6	21
	14	19
	22	16
	30	14

δ LIBRÆ.

	d	h
Feb.	2	19
	7	11
	12	3
	16	18
	21	10
	26	2
Mar.	2	17
	7	9
	12	1
	16	17
	21	8
	26	0
	30	16

S. CANCRI.

	d	h
Feb.	1	5
	10	16
	20	4
Mar.	1	16
	11	3
	20	15
	30	3

+45°3062

	d	h
Feb.	6	16
	15	19
	24	23
Mar.	6	3
	15	6
	24	10

Z HERCULIS.

	d	h
Feb.	2	3
	10	3
	18	3
	26	2
Mar.	6	2
	14	2
	22	1
	30	1

NOTES TO THE EPHEMERIS.

The above data are adapted from the table given in the *Companion to the Observatory*, where the times are reckoned from Greenwich midnight. To change to the astronomical reckoning, 12^h has been subtracted from the times given in the *Companion*.

The star + 45°3062 is called U^3 Cygni in the *Companion*, but as no letter has been assigned by Dr. Chandler the Durchmusterung designation is retained here.

NOTATION OF RECENTLY DISCOVERED VARIABLES.

A provisional notation for new variables, similar to that used for comets and asteroids, has been adopted by the editor of the *Nachrichten* with the approval of the directors of the *Astronomische Gesellschaft*. The new discoveries of each year in the order in which they are made known to the editor, receive the numbers 1, 2, 3, and so on, followed by the year and the constellation in which they are located. This notation will be used in the *Nachrichten*, only until the variability is confirmed and the star receives its permanent letter and number in the usual manner.

The designations for the stars discovered in 1900 is given as follows in *A. N.* No. 3765.

			Place 1855.			Reference,		
			h m s	° ′				
var. 1	1900	Draconis	17 55 36	+54 51	Anderson	AN 3618	PA 8,215	
2	"	Cygni	20 28 10	46 6.1	Williams	AN 3629	PA 8,288	
3	"	Andromedæ	0 8 30	46 12	Anderson	AN 3632	PA 8,288	
4	"	Tauri	5 44 6	15 45	Anderson	AN 3634		
5	"	Cassiopeiæ	23 48 24	52 55	Anderson	AN 3634		
6	"	Tauri	5 30 30	+26 17.1	Ceraski	AN 3635		
7	"	Virginis	13 00 18	−12 23.1	Schwassman	AN 3636	Yerkes 13	
8	"	Aurigæ	6 00 54	+50 14	Anderson	AN 3642		
9	"	Cephei	0 28	79 33	Ceraski	AN 3644		
10	"	Herculis	18 30 55	+25 55.8	Ceraski	AN 3650		
11	"	Aquilæ	19 12 57	− 0 24.0	Fleming	AN 3636,53		
12	"	Lyræ	18 32 51	+43 49.6	Williams	AN 3670	PA 9,49	
13	"	Cygni	19 42 02	48 42.8	Hisgen	AN 3669	PA 9,48	
14	"	Pegasi	22 04 36	13 38	Anderson	AN 3670	PA 9,49	
15	"	Lyræ	18 54 21	34 45.5	Williams	AN 3671	PA 9,49	
16	"	Cygni	20 28 34	46 04.2	Kohl	AN 3673		
17	"	Aquilæ	19 33 48	9 35.4	Anderson	AN 3373		
18	"	Pegasi	21 06 15	+12 12.4	Anderson	AN 3673		
19	"	Puppis	7 26 07	−20 20.3	Innes	AJ 485		

The references are to the number of the *Nachrichten* (AN) and the *Astronomical Journal* (AJ); the volume and page of POPULAR ASTRONOMY, and to the Bulletin of the Yerkes Observatory.

One correction and one addition should be made to the above list. The star 19.1900 Puppis is identical with 2689 Z Puppis, discovered by Arthur C. Perry (AJ 398 and 428). This correction is made in AJ 486 and AN 3676. Professor Barnard's variable in the cluster Messier 13 should be added. (See *Astrophysical Journal*, XII, 182 and POPULAR ASTRONOMY, VIII, 486.)

DOUBLE-STAR NOTES.

In the *Astronomical Journal*, No. 486, Cogshall gives a long series of measures with the 24-inch refractor of the Lowell Observatory of double stars previously discovered with that instrument, principally by See during his work at Flagstaff. Some changes are shown by these measures. A few of the pairs he has been unable to find in the places given. In the case of close pairs this may be explained by rapid orbital motion.

Hussey at Mt. Hamilton has found the companion to β 168 to be a close pair. The distance of the components is less than 0″.4. As the wide pair was measured by the same observer on five nights in 1896, without detecting the duplicity of *B*, there may be rapid motion in this pair.

Recent measures of β 1026 by Aitken confirm the direct angular motion shown by the measures of 1888 and 1899. The change in angle is about 20°. The rapid motion of β 953 still continues. It is now a very close pair and only a slight elongation with the 36-inch. The same observer finds that β 949 is rapidly closing and the distance now is less than 0″.2.

Recent measures of β 363 when compared with the first observations by β in 1878 and Wilson in 1892 show that the principal star has an annual proper motion of about 0″.13 nearly in the direction of the twelfth magnitude companion. It does not appear in the catalogues of proper motion stars.

The principal component of Σ 325 has a large proper motion for so small a star. The measures of Struve, Dembowski and Aitken (1830 to 1897) give an annual movement of 0″.16 in the directionof 302°. As the comparison star is very small, the change is probably due to the proper motion of the other, the magnitude of which according to Struve is 8.2. There does not seem to have been any investigation of this based on meridian observations. It is D.M. (33°) 542.

No. 485 of the *Astronomical Journal* contains a second catalogue of 100 new double stars discovered by Hussey at Mt. Hamilton with the twelve and thirty-six inch refractors. Of this number 25 have distances of less than 0″.5. All are telescopic stars with the exception of τ Capricorni. This is a close and difficult pair, the measured distance between the components being only 0″.17. It is certain that this catalogue in the future will make many additions to the list of binaries.

COMET NOTE.

New Comet *c* 1900 (Giacobini).—A comet was discovered by Giacobini, at Nice, Dec. 20. It was then in the constellation Aquarius about 10° north and a little west of the star Fomalhaut. It has been moving almost due east and is now in the eastern part of Cetus. It is a faint small telescopic comet and, according to the preliminary elements which have been calculated, is growing fainter so that there is no prospect of its becoming a conspicuous object.

In the *Science Observer*, Special Circular, No. 128, the following positions of the comet are given, the last three of which were obtained at Lick Observatory:

POSITIONS.

Greenwich M. T. 1900	R. A. h m s	Decl. ° ′ ″	Observers.
Dec. 20.313	22 32 0.0	−22 0 0	Giacobini
24.271	22 57 0.0	−22 45 0	Giacobini
24.6025	22 59 10.2	−22 44 40	Aitken
26.6280	23 11 23.6	−22 57 59	Aitken
28.6197	23 23 17.1	−23 7 30	Aitken

From the three Lick positions Mr. Aitken has computed the following orbit:

ELEMENTS.

$T = 1900$ December 1.41 Gr. M. T
$\omega = 175°\ 54'$
$\Omega = 192\ \ 39$ } Mean Eq. 1900.0
$i = 31\ \ 1$
$q = 0.9769$

EPHEMERIS.

Greenwich Midn. 1901.	R. A. h m s	Decl. ° ′	Light.
January 3	23 57 44	−23 14	.74
7	0 20 8	−23 2	
11	0 41 36	−22 37	
15	1 2 8	−22 2	.55

Light at discovery = 1.

GENERAL NOTES.

Honor for E. E. Barnard of Yerkes Observatory.—We extend congratulations to E. E. Barnard in view of the award of the Janssen Gold Medal of the Academie des Sciences, Institut de France. It was given Dec. 17, 1900. We have not yet seen an account of the action of the Institute.

J. A. Parkhurst has recently received the appointment of assistant at the Yerkes Observatory. On this account our publication will lose one of its most efficient helpers in regular editorial work. For eight years Mr. Parkhurst has presented in this publication, from month to month, the current matter pertaining to variable stars with rare fidelity and exceptional ability. His promotion is richly deserved.

Extract from Letter of M. Loewy to the Astronomical Director of the U. S. Naval Observatory Concerning Observations of Eros.—Before all it seems to me necessary to prepare tables of all the observations of Eros, micrometric and others. The data will be sufficient to permit in the first place the reduction of all the photographic plates relating directly to all the parts of the planet's path in which Eros has been observed.

In the successive bulletins of the International Committee there can be published in a compact form, and as rapidly as possible, outside the table of observations of Eros above mentioned, the results of the observations giving in a few lines at most the necessary explanations. Each Observatory could furnish later in its annals or memoirs all the details of the methods used and the reductions employed.

The publication of the zero stars of the plates and the comparison stars will naturally come first, but the publication later of the positions of Eros is equally necessary in order to determine its diurnal motion when this is lacking, and also for the final presentation of all the data. Each astronomer would thus have at his disposition a resumé of all the material necessary for conducting a research of the solar parallax so far as concerns his individual work.

I will do all in my power to carry out as soon as possible the publication of the first two works, the positions of the zero and comparison stars. To secure this I ask you on your part to see that the American observatories undertake without delay the reduction of the meridian observations of the zero and comparison stars.

The Great Fireball.—On Friday afternoon, December 7, 1900, there passed across Colorado and Wyoming a brilliant meteor, which is said to have rivaled the Sun in the intensity of its light. It seems to have burst near the northern boundary of Colorado; horses and cattle were frightened by it. If a sufficient number of accurate reports can be obtained from those who saw the meteor or heard its reverberations, it will be possible to determine its path, and to find out its fate. It may have been burned up, or it may have come to the Earth in a shower of fragments; possibly it escaped from our atmosphere and went off into space before it was entirely consumed.

As it is probable that this wonderful meteor will become an historic one, observers of it are urgently asked to send full reports to the undersigned at their early convenience. The following points are worthy of special attention:

1. Where was the observer, and in what direction did he face? 2. Did the meteor pass *directly* overhead? If not, did it go north of the zenith, or south of it? 3. For how many seconds was it visible? 4. Was it seen to split up? 5. Describe the sound it made, if any was heard. 6. How long after the passage of the meteor was the sound heard? 7. Was any heat from it noticed? 8. Describe its size, shape, brightness and color. 9. Did the meteor fade away gradually, or was it suddenly extinguished, while still bright? 10. When first seen, how many degrees above the horizon was it? How many degrees when it burst? How many when it vanished? 11. When first seen, in what direction was it from the observer? In what direction when it burst? In what direction when it vanished? 12. In what direction did it move?

Any postmaster who receives copies of this circular will confer a special favor by posting one of them in a conspicuous place. In case the meteor was neither seen nor heard at any particular town, a postal stating that fact will be highly appreciated.

HERBERT A. HOWE.

UNIVERSITY OF DENVER,
December 22d, 1900.

Observation of Eros.—Bulletin No. 6 of the International Astrophotographic Congress of July, 1900 was issued from Paris by the President, M. Loewy, Dec. 4, 1900. It contains a number of reports and suggestions concerning the work of observing Eros, followed by ephemerides of 81 of the Fundamental Stars of Newcomb's catalogue which may be used in determining the positions of the reference stars for Eros.

Two new observatories are reported as undertaking to determine the places of the reference stars, viz., the Observatory of Charkow, directed by M. L. Struve and that at Abbadia directed by the Abbé Verschaffel.

Heliometric observations were begun at Bamberg on Sept. 21. Dr. Hartwig was able on the 8th or 9th of October, under excellent conditions to connect Eros with the stars of reference.

It is suggested as desirable that those taking photographs of Eros should at least once on each favorable night make two exposures longer than necessary to secure the image of the planet upon the plate; the one for example of six minutes the other of three minutes duration. This will add a considerable number of supplementary observations of the comparison stars and affords new means of verifying the accuracy of the photographic process. It will be possible thus to ascertain certain effects of the movement of the planet and especially to assure ourselves whether or not the measures made upon the trails of the planet are independent of their dimensions.

Several astronomers, notably Messsrs. Barnard, Brown and Howe have found it necessary to use stars fainter than the 11th magnitude for comparison stars of Eros, and it becomes important to determine whether these fainter stars, going down sometimes to the 12.5 magnitude are to be found with measurable images upon the photographic plates. At Paris it has been determined that upon the plates exposed for 6 minutes a great number of images of stars of the 12th magnitude are visible and are quite measurable.

At Algiers, M. Trépied took a photograph of the Pleiades giving an exposure of five minutes and found that of 24 stars, whose photometric magnitudes Pickering gives as from 11.5 to 12.5 only six were missing and these ranged according to Pickering, from 12.3 to 12.5 magnitude.

It was thought by some before beginning the work that comparison stars could always be found within 1′ of the planet. M. Trépied has examined 24

plates which were exposed along the zone to be traversed by Eros, counting the stars to be found within fields of 6′, 10′ and 14′ diameter at the centers of the plates. On 8 plates, or one-third of the whole number, no star is found within 3′ of the center and upon one there is no star within 5′ of the center. The averages however, show one star within 3′, three within 5′ and six within 7′ of the center. It would thus seem that the micrometer measures of Eros, when connected with stars which are to be found upon the photographic plates must frequently extend over arcs of 5′. The results can therefore hardly compare in accuracy with the measurements of double stars.

In order to be sure of the 12th magnitude stars it is recommended that those undertaking the special series of photographs of the stars of reference should prolong the first of the two exposures by as much as one minute and that the second exposure should be carried to at least five minutes, in order to avoid mistakes in identifying the feebler images.

It is gratifying to learn that on four nights in October the evening observations by Barnard with the 40-inch telescope of Yerkes Observatory coincide closely in time with photographic observations obtained in the morning at Paris and at Cambridge, England, and it is likely that when all the observations in Europe and America are brought together there will be found a large number of simultaneous observations at widely separated points on the Earth.

The following method of determining the direction of the diurnal motion with the position micrometer is suggested by Professor Comstock and is said to give the parallel within one-half minute of arc.

Turn the instrument on the region where the planet will be found at the mean epoch of the observation. Designating by P_0 the reading of the position circle at a reading P_1 approximately 3° greater than P_0, set the movable wire of the micrometer at a convenient distance, say 15″, from the fixed wire. Under these conditions a star, chosen preferably of the 8th or 9th magnitude, in traversing the field of the telescope will strike obliquely the two wires thus inclined to the apparent direction of the parallel. Let τ_1 be the interval of time elapsing between the two successive transits of the star over the two wires; turn the position circle so that the reading P_2 will be about 3° smaller than P_0 and call τ_2 the interval of time between the consecutive transits of the same star over the two wires. Then the direction of the parallel will be given by the following formula:

$$P_0 + \rho = \frac{1}{2}(P_1 + P_2) + \frac{1}{2}(P_1 - P_2)\frac{\tau_1 - \tau_2}{\tau_1 + \tau_2}.$$

The last term of this equation is a small correction of which the sign may be determined by this rule: If τ_1 is greater than τ_2, P_0 is nearer P_1 than P_2.

The letter ρ represents a small correction due to refraction for which Mr. Comstock proposes to derive the analytical expression. Each of the two values of τ being in practice deduced from four transits the probable error of P_0 will be less than a half minute of arc. The apparent direction of diurnal movement being thus calculated for the position of the instrument corresponding to the mean epoch of the measures, the result will be independent of flexure and of errors of orientation of the telescope. H. C. W.

Capella a Visual Double Star.—At the December meeting of the Royal Astronomical Society the Astronomer Royal read a paper on observations of Capella as a double star with the 28-inch equatorial of the Royal Observatory at Greenwich. He said that Fellows would remember that, acting on a suggestion

made by Mr. Newall as a result of his spectroscopic observations in which he announced the discovery of Capella as a binary star, Mr. Dyson and Mr. Lewis examined the star last April, and discovered that it was visually double. The observations were continued, and the first results were published at the June meeting of the Society. These observations have been continued since at every available opportunity, and Mr. Bryant in particular has watched for Capella at every chance, especially in the daytime, and a considerable number of observations have been accumulated, the double star having been watched through 2½ revolutions, the period of a revolution being 104 days. Naturally in this case they had to depend practically upon position-angles, the estimates of distance being, of course, rather difficult to make. On the diagram three circles had been drawn, on which the observed position-angles had been marked corresponding to the three revolutions which had been under observation. There was an indication from the visual observations that the period might be 103 days, but there might be personality in the observations which might affect that. In the first revolution Capella was observed in the evening twilight, afterwards in the daytime, and latterly east of the meridian in the evening. The first thing which appeared to result from these observations was that the apparent orbit was not very far from circular. There appeared to be a small eccentricity of about 0.05, and the inclination came out as 30° to 35°, the line of nodes agreeing well with the spectroscopic determination of maximum velocity in the line of sight. For the last four observations of Capella κ Pegasi, which was now closing in, was observed on the same nights by the same observer, and it was found that the elongation of Capella was as distinct as of κ Pegasi. In Mr. Lewis's last observation of Capella on December 10, although he was not able to get a satisfactory measure of the position-angle, he satisfied himself of the elongation, and the definition was so fine that he was able to *count* eight complete rings round the star, there being ten or more rings visible. This might serve to indicate that the definition at that time was exceptionally good. These observations were made under great difficulties during fits of fine definition which were usually very short, and it was greatly to the credit of the observers that they had watched so patiently for those fits of fine definition, and that they had managed to secure observations of Capella on some 40 days.

It should be added that at the Lick Observatory Professor Hussey (*Astronomical Journal*, No. 484) examined Capella on several afternoons early in June with the 36-inch telescope without obtaining any visual evidence of its being a double star. The seeing, though good, was not rated as excellent, so the results were not regarded as conclusive. On the nights of August 2 and 5 Professor Hussey again examined Capella using powers 1000, 1500, 1800 and 2600. With all powers the star appeared round and the seeing was excellent. With such conditions as then prevailed an elongation of a tenth of a second would have been readily perceptible with the lowest power used and a considerably smaller distance would have been noted with the higher ones. H. C. W.

The Bruce Photographic Telescope.—The Bruce telescope has remained, during the year, under the special care of Dr. Stewart. Work has generally been carried on with this instrument, however, during the last part of the night, by Mr. W. B. Clymer or Mr. R. H. Frost. During the year, 760 plates have been taken, making 4,767 in all. Many photographs of the planets and other special objects have been made by Dr. Stewart. From an examination of 319 plates he has found, in addition to those already announced, 198 new faint

nebulæ. On these plates were also noted 92 asteroid trails and 2 meteor trails. On one photograph, no less than 7 trails of asteroids are visible. Last spring, a successful attempt was made to obtain photographs of the planet Eros when it was too faint to be observed in other ways. An eye-piece was connected with the photographic plate by means of a micrometer screw, and the axis of the latter was placed parallel to the motion of Eros. A star was followed by means of the eye-piece, while a motion equal to that of Eros was given to the plate by means of the screw. Three excellent plates were thus obtained on April 28, 30 and 31, 1900. in which the stars appeared as trails and Eros as a circular image. These observations preceded those taken elsewhere, by one month. A long series of photographs of the planet Saturn was taken, to determine if possible the orbit of the satellite, Phoebe. From an examination made in Arequipa the existence of this object has not been confirmed, and the plates have not yet reached Cambridge. A careful examination of them will be made here.—From the annual report of Harvard College Observatory for the year ending Sept. 30, 1900.

The Harvard College Observatory Equipment.—From the last annual report of Professor E. C. Pickering, we take the following statement in regard to the equipment and needs of the Observatory:

"In my last report, it was shown that the annual income of the Observatory amounting to nearly $50,000, places it, in this respect, on an equal footing with the principal observatories of the world. Its work, however, can be maintained only if all the income is devoted to current expenses, and this becomes every year more difficult, owing to the continued diminution in the rate of interest on invested property. The additional sum of $200,000 would be required to secure permanently the income of six years ago. When a comparison is made with the buildings and instruments of other observatories the result is still less favorable. The estimated value of the buildings at Cambridge is $52,000, at Arequipa $12,000; of the instruments at Cambridge $20,000, at Arequipa, $50,000. About half a million dollars have been expended on the buildings and instruments of the Lick Observatory, and an equal sum at the Yerkes Observatory. Great additions have been made within the last few years to buildings and instruments at all the principal national observatories of the world. The main building at Cambridge is of wood, and is more than half a century old. It contains one of the finest astronomical libraries in the world, and this is in constant danger of destruction by fire. To save unnecessary expense, the new buildings erected here are as plain as possible, and the lack of architectural effect should be ascribed to this reason, and not to the taste of the Director. Even allowing for the recent increased cost of building materials, $100,000 would supply our present wants, by furnishing plain buildings of modern construction. One of the greatest needs of astronomy at the present time is a large telescope mounted in the southern hemisphere. Nearly all of the largest telescopes of the world are north of latitude + 30°, and only one or two of them are located where the condition of the air permits work of the highest grade to be done. In many departments of astronomy, no work of this character has been undertaken on any of the extreme southern stars. The cost of a telescope of the largest size would be about $100,000, and an equal sum would be required for a building and the incidental expenses, which would prevent its curtailing the work of the other departments of the Observatory. It will be seen, therefore, that the sum of half a million dollars is required to enable this Observatory to maintain its place among the greatest observatories in the world.

Nature of the Solar Corona.—In a letter to the editor of *Nature* Jan. 3, 1901, Mr. R. W. Wood of the University of Wisconsin makes some very important suggestions as to observations which might be made in order to determine the nature of the solar corona. These are based upon the supposition that the light emitted by the particles of the corona, by virtue of their incandescence, so overpowers the reflected sunlight that the Fraünhofer lines are invisible. That the coronal light is strongly polarized is well known, and there is scarcely any doubt but that the polarized light is reflected sunlight. If, now, a Nicol prism be placed before the slit of the spectroscope in such a position as to transmit the polarized radiations, these will be allowed to pass with almost undiminished intensity, while the emitted or unpolarized light will be reduced in intensity by one-half. The great change in the resulting ratio might easily be sufficient to bring out the dark lines distinctly.

Mr. Wood has successfully performed this experiment in the laboratory with an artificial corona and feels firmly convinced that it should be tried on the real corona at the Sumatra eclipse of next May. A full account of Mr. Wood's experiments will soon appear in the *Astrophysical Journal.*

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